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CONTENTS

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GROWTH IN LIVING AND NON-LIVING SYSTEMS

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GROWTH has perhaps a better claim than any other life-process to be called "fundamental," since it is the indispensable basis or condition of all vitality. This is true not merely in the obvious sense that all organisms are products of growth; even when an animal or plant has ceased to "grow," *i. e.*, add to its total living or organized material, it continues automatically to renew its own substance and to repair losses and damage; without this continual renewal no life can persist. We may thus regard the adult organism as still "growing," but the growth is "latent"—masked by the simultaneous loss inseparable from all vital activity. Visible increase in size is thus not the only evidence of growth; whether an organism grows visibly or not is in fact determined by the relative rates of two opposed processes, one of which builds up and accumulates, while the other breaks down and dissipates. In all life the primary or fundamental process is the building-up of the specifically organized living substance by constructive metabolism; but this process is always accompanied by chemical breakdown or destructive metabolism, with loss of material to the surroundings. Briefly, therefore, we may describe the essential situation as follows: when metabolic construction exceeds destruction there is "growth" (in the ordinary sense of visible increase); when the two are equal there is balance, or simple maintenance; when destruction predominates there is regression or atrophy. Visible growth represents simply the accumulated excess of construction over destruction.

This constant association of destruction and repair has long been recognized as the essential or distinguishing peculiarity of the living state; while the organism "lives," the effects of loss or destruction are continually being offset or compensated (often over-compensated) by new construction. The life process is thus

fundamentally a process of construction; it is a synthetic or creative agency; and all of its special peculiarities as a natural process are expressions of this characteristic power of specific synthesis. Claude Bernard has given perhaps the clearest and most comprehensive expression of this fundamental fact, which was already perceived by Lavoisier and in a vague way appreciated even in ancient times (*cf.* Heracleitus). The following passage is characteristic:[1]

> The synthetic act by which the organism maintains itself is at bottom of the same nature as that by which it repairs itself when it has undergone mutilation, or again by which it multiplies and reproduces itself. Organic synthesis, generation, regeneration, reintegration, healing of wounds (cicatrization) are different aspects of an identical phenomenon. . . .

Bernard's characterization is well known; "la vie, c'est la création;" he thus emphasizes the all-importance of construction or synthesis in the vital process.

Living material, then, is primarily *growing* material. In higher organisms this is sufficiently obvious in early development; later it becomes less and less evident because of the progressive increase of the destructive processes—relatively to the constructive—in the total metabolism. It is clear, however, that without the continuance of the synthetic processes which determine growth there can be no continued life at any stage. Growth therefore must be regarded as the universal index of the presence of life. We recognize this in the case of lower organisms like bacteria; and test their "livingness" by determining if they are capable of growth; if there is no proliferation in the culture medium the culture is a sterile one; either no organism were introduced, or those introduced were "dead."

Most multicellular animals and plants reach their final or adult stages through a process of progressively increasing size and complexity, beginning usually with a small and structurally simple germ (*e. g.* egg-cell); we describe this germ as "developing into" or "growing into" the adult form. This verbal usage expresses incidentally the necessary dependance of reproduction on growth. The growth involved in a single reproduction is often very extensive; thus the ratio between the mass of an adult human being and that of the fertilized egg-cell from which he develops is approximately fifteen billion to one;[2] this enormous accumulation of material occurs in each reproduction. There may, however, be reproduction without simultaneous growth (certain cases of fission) as

[1] Leçons sur les phénomènes de la vie, Vol. 2, p. 517.

[2] *I. e.*, the ratio of the mass of an individual of 60 kilo to the mass of an ovum of 200μ diameter (volume about .000004 c.c.).

well as growth without reproduction, and it is important to realize clearly the general nature of the organic processes which these terms represent. This may best be done by considering the case of micro-organisms; here the two processes are less sharply distinguishable and the terms are often used synonymously; thus bacterial growth and bacterial reproduction are usually regarded as identical. In such cases, reproduction simply follows automatically and regularly upon growth, so that the two are not practically separable; the one involves the other. Reproduction has been defined as "discontinuous growth," and this phrase expresses a conception which seems to be universally applicable. The essential fact in every case of reproduction is that portions of the growing organism continue to grow after detachment from the parental stock, and in so doing give rise to other complete organisms of the same kind. Reproduction of higher plants by cuttings is a case in point and in animals asexual reproduction and regeneration of the whole from a fragment afford similar instances. From such cases the logical transition to cases of gametic reproduction is simple; in this case the detached portion is a specialized unicellular structure (egg-cell) requiring fertilization in order to start its cycle of growth; but it represents none the less a detached portion of the parental organism.

What we observe in the case of higher animals is that when we trace the organic individual back to its beginning—or at least to the stage usually regarded as the beginning of individual life—we come finally to a small often microscopic mass of protoplasm, usually a single cell (germ-cell) which itself is the product of growth from the parent organism. In this germ we see little or nothing of the characteristic organization of the adult. Yet it is by the progressive accumulation and transformation—through the activity of this at first minute portion of living substance—of materials taken from the surroundings that the adult organism is by degrees built up.

Let us now consider briefly, from the point of view of general physiology, the essential nature of this process of growth or upbuilding, which we call individual development or ontogeny.

The germ adds to its substance, or *grows*, by incorporation of non-living materials taken either from the surroundings or from its own reserves (yolk),—food, water, salts; these it transforms physically and chemically in a definite manner which is specific for each organism. The most remarkable chemical feature of this transformation is the predominance of certain complex syntheses, especially the synthesis of colloidal substances of high molecular weight and highly specific or individualized chemical constitution.

These are the proteins, which are regarded by most biologists as forming the basis of organic specificity. Part of these substances, together with certain other products of the metabolic transformation, are chemically stable under the conditions prevailing in the living system, and are laid down in definite situations and at definite times in the form of a more or less solid, resistant or permanent residuum or deposit which forms the structural substratum of the growing organism. And since the rate of these synthetic or constructive processes exceeds that of the accompanying destructive processes, especially in the early stages of development, the living and organized material steadily accumulates; in other words, the organism grows. The rate of growth is not uniform in different regions; usually certain regions proliferate actively at certain times; then, as their growth activity subsides, other regions become active; the existence of growing zones or growing apices (buds or shoots in plants) is in fact one of the most characteristic features of developing organisms. All of this growth proceeds in an orderly and definite manner, in regular sequence and with strict correlation between the rates of growth in the different regions. Eventually the whole system acquires a more or less permanent form and dimensions, corresponding to the adult state; after this stage is reached the constructive processes gradually become less and less active, and eventually they fail to offset the destructive processes. Natural death then follows.

As the germ or embryo grows it "differentiates," *i. e.*, becomes by degrees more and more diversified, structurally, chemically, and physiologically. Different regions are set apart as the seat of special formative processes which give rise to special morphological structure with corresponding special physiological activity, and by degrees the systems of organs so clearly distinguishable in the adult make their appearance. The development of correlating or integrative mechanisms goes hand in hand with this differentiation. It is customary to regard differentiation as a process distinct from growth, since its essential feature is the appearance of new qualitative characters, both structural and functional, *i. e.*, of diversification; while the term growth has a primarily quantitative significance and has reference to increase in size, considered as such. Differentiation in embryonic development is perhaps the most impressive and mysterious of all organic processes, and its apparently purposive character has long furnished the vitalists with their strongest arguments. In the multicellular organisms it appears to have acquired a special physiological basis or determinative mechanism which has become superposed on that of simple growth—as we find it in unicellular organisms where cells give

rise typically only to other cells of the same kind. Apparently some additional factors, which impart definite and special directions to the formative processes in different cell-groups, are present in the higher organisms; and the evidence from genetic and cytological studies indicates that this special basis for differentiation is to be found in the specific differences between the chromosomes of the germ-cells. In some way, depending apparently on the manner in which the elementary chemical components of these structures are sorted or distributed in the series of mitotic cell-divisions, special kinds of structure-forming metabolism are localized in definite regions of the developing embryo.

The "chromosome theory of heredity" has performed notable services and is probably true, even if it is not the whole truth. But it should not be overlooked that growth and heredity, in their most general aspects, must be independent of special mechanisms of this kind. Specific growth and its manifestation in heredity are the final or visible expressions of the property of specific metabolic construction, which is based on specific chemical synthesis and is possessed by all forms of living matter—we may even say by all living structures which preserve their identity during the life of the cell or organism of which they form part. The chromosomes themselves grow and reproduce, and this capacity can hardly be referred to the existence of sub-chromosomes; in this respect chromosomes are like all other living structures. This, however, need not prevent their having a special function as repositories and distributors of substances which control the special nature of the structure-forming metabolism in different parts of the organism.

While in higher organisms growth and differentiation, considered abstractly, may be regarded as two distinct processes, in reality the two are inseparable, and on a strictly objective view these terms must be regarded as denoting two aspects of a single complex process rather than two essentially different processes. "Growth" is usually given a quantitative definition, as signifying increase in the quantity or mass of the living material; thus we may express the growth of an embryo in mass-units or weights and draw curves showing correctly, within certain ascertainable limits of error, the rate of growth from day to day. But while this growth is proceeding it is in fact associated with increase of complexity, with the continual appearance of new qualities and activities in the organism. These features of the total organic process differ from growth in not being representable in simple quantitative terms and in requiring special methods of description; yet they are all *based* upon growth. Such considerations illustrate the sense in which the growth-process is fundamental or

foundational in all life-processes. Obviously without its occurrence the adult organism could never arise from the minute "undifferentiated" egg-cell. Whatever the special nature of the formative activities may be, it is at least clear that they must have material to work on, and this material is furnished by growth.

Increase in the quantity of organized or living material is simple growth, and proceeds automatically in all forms of protoplasm under favorable conditions. Increase in structural or organizational complexity is usual when growth is associated with *development*—as in higher organisms—but is not always present; thus we do not usually conceive of development as occurring in dividing bacteria or yeast cells. In the lowest organisms the result of growth is the formation of more and more living material of the same kind, simple and "undifferentiated," structurally and physiologically. For example, there is no progressive increase of complexity during the growth of bacteria in a culture medium—except in so far as this is necessarily involved in any quantitative increase; more and more protoplasm of the same kind, definite and specific in structure and activity, is built up from the environmental materials by a strictly repetitive kind of process. We may note here, as a matter of general or philosophical interest, that it is simply because the same series of transformations is repeated in each bacterium as it grows and divides that we conceive of the process of reproduction as involving "heredity." The daughter-cell repeats the life-cycle and hence the qualities and activities of the parent-cell. If we wish, we may express this fact by saying that it "inherits" its qualities from its parent; but this terminology need not confuse our conceptions of what really and objectively occurs. In higher organisms we have the same type of situation, except that a more complex cycle of metabolic and formative transformation is repeated in each reproduction. In either case the *constancy* of the metabolic syntheses which underlie the growth-processes forming the new living material is what makes possible the constancy of the outcome in the growth and development of the individual organism, whether this organism be a bacterium or a human being.

In many animals evidence of differentiation is seen early in development, *i. e.*, before the germ has proceeded far in its growth. Even uncleaved eggs show partial differentiation in many cases. In the vertebrate embryo the various systems of organs, nervous, skeletal, digestive, circulatory, are distinguishable soon after the germ layers are formed; these embryonic foundations, once established and partly individualized, continue to grow and soon exhibit secondary differentiations; their functional activity and interdependence increase at the same time. Each organ system is

often described as if it developed independently by inherent potencies of its own; but this is merely an accident of descriptive procedure, where the whole is often disregarded in considering the details. In reality no organ system or other part develops in isolation. The growth and development of the organism as a whole is marvellously balanced and correlated; a system of checks and controls prevents the excessive growth of one region at the expense of another. The shape and proportions of the embryo at each stage of development are as constant as they are in the adult; and a similar constancy must characterize the underlying physiological processes. The problem of the physiological conditions determining the correlation of growth processes in organisms has many aspects of fundamental interest. It includes the special problem of the nature of transmissive processes in protoplasm (nervous and related transmissions), as well as the broader biological problem of the unification or integration of the various organic processes of the individual. The unity of the formative processes represents a special feature of organic unity in general, and cannot be considered apart from other cases of functional integration. Development is perhaps the most striking example of an organic activity which is at the same time highly complex and highly integrated.

The final or adult stage of even the highest animals is attained with a constancy and exactitude which never fail to arouse our wonder. We cannot trace the causal sequence in any detail and may never be able to do so. And yet when we consider the matter more closely, and especially when we observe the degree to which exactitude—constancy of repetition—is inherent in all natural processes (as the achievements of physics and astronomy show perhaps most clearly), it ceases to be a matter of special surprise that organic processes like growth and development should exhibit a similar regularity. If, as physiology assumes, the organism is a synthesis of simpler physical and chemical processes, its activities should partake of the regularity of the component processes. In fact, a similar quantitative regularity becomes apparent whenever single organic activities are isolated and presented to observation in a form suitable for measurement. Accordingly, with constancy of initial constitution and constancy of environing conditions we should expect a living germ, like any other natural growing system, to exhibit constancy in its cycle of development. That it does show such constancy is the very fact which we designate as "heredity." Many years ago Professor C. O. Whitman gave clear and striking expression to this thought in the following words: "Germcells behave alike in development, not because anything is transmitted to them, but because they represent identical material and

constitution and are exposed to essentially like environmental conditions." And with respect to the exactitude of development he says: "We easily forget that only physical processes can approach such exactness."[3] We may safely assume that given a germ of a definite constitution and normal environmental conditions, a "spiritus rector" is as little needed to guide development along a constant course to a definite or predetermined end as to guide the course of the planets about the sun. Constancy in the initial constitution of the germ, and in the environmental conditions implies constancy in the sequence of physical and chemical transformations which form the basis of growth and development.

Although the developing organism is a highly unified or integrated system, yet many facts, especially those of tissue culture and certain departments of experimental embryology, show that the cells forming each system of organs have an independent power of growth; when they are isolated in sterile plasma and supplied with oxygen they will continue to proliferate and give rise to other cells of the same kind. An isolated part of an embryo will undergo differentiation; or if it is transferred from its normal position in the embryo to a distant region in the same or another embryo (as in grafting experiments) it will continue, for a time at least, with its usual development and differentiation. Such facts illustrate again the specific nature of the formative processes or powers of growth innate in each form of protoplasm; when it grows it gives rise to other protoplasm of the same kind, similarly constituted structurally and with a similar chemical organization and similar physiological activities. We have evidence, in the existence of specific cytolysins, of the chemical differentiation of the different tissue-proteins of the same animal, just as we have evidence of specific chemical differences between the corresponding proteins of different animals. While our most delicate means of discriminating between different native proteins are the biological tests, especially those of anaphylaxis and precipitin-formation, which do not give us direct information of chemical constitution, yet we cannot doubt that the structural proteins of each species of cell have specific or highly individualized peculiarities of composition and configuration; and that these peculiarities are related in a definite manner to the specific structural and physiological peculiarities of the cell. Reichert has shown that the hæmoglobins from different animals have specific crystallographic peculiarities; *i. e.*, in separating from solution they form aggregates of specific form and structure. No doubt the same process occurs in the case of

3 See Vol. 2, pp. 179, 180, of Whitman's posthumous Studies on Inheritance in Pigeons (Carnegie Institution, 1918, edited by O. Riddle).

the other cell-proteins as they are deposited during growth to form the protoplasmic structures characteristic of the species; if this is the case, the specific morphological or histological features of a given cell must depend ultimately upon the specific features of chemical structure and configuration possessed by the cell-proteins. The toxic effects of foreign proteins upon cell-structure, as seen (*e. g.*) in specific hæmolytic effects, are an indication of the incompatibility of such compounds with the normal cell-structure of the species.

In all cases the cell-proteins, like the majority of cell-constituents other than salts and water, are synthesized within the cell by the processes of specific constructive metabolism from materials furnished by the surroundings. Since in general every chemical compound, when it is deposited in solid form from a solution, forms a definite type of structure, seen in constancy of crystal form, it is to be expected that in living protoplasm the formation and deposition of chemical compounds with specific chemical characters will involve the origination of specific structure, and secondarily of specific physiological activities corresponding to that structure.

In general any solid material with a specific chemical composition must possess a specific physical structure. This conclusion is not merely a generalized inference from the facts of crystal-formation, special texture or other properties of solids, but has been brilliantly substantiated by the methods of X-ray analysis of crystal structure recently developed in England by W. H. and W. L. Bragg. And we may infer that the special features of the new structure formed in any growing system, whether living or non-living, will have a similar dependence on the chemical composition of the structural material.

The study of the structure and properties of growing inorganic systems, especially as related to the chemical composition of their components, may thus be expected to throw some light upon the more general features of the growth-process in organisms. Such systems may be regarded as elementary or generalized models of organic growth. Organic growth is peculiar in the complexity of its materials, conditions and outcome; it gives rise to the highest products of synthesis found in nature; but in other respects it shows various definite affinities with certain types of inorganic growth. It may be of interest, therefore, to consider briefly some results of a study which I have recently made of certain inorganic growth-models, and their bearing on some of the more general problems of organic growth.[4] In particular the conditions determining the structural specificity of these inorganic growths, and

[4] *Biological Bulletin*, 1917, Vol. 33, p. 135, and 1919, Vol. 36, p. 225.

the manner in which they are influenced by external conditions (electricity, contact, temperature, presence of foreign chemical substances), show certain resemblances to organic growth which seem to throw light on some of the more fundamental features and conditions of the latter.

It is well to realize that growth processes are by no means confined to living organisms, but are to be found everywhere in nature—in other words that organic growth is a special example of a universally distributed type of natural process. Hence the analysis of what growth is, in its more general and simpler aspects, must be a matter of great interest to all biologists. The more special problem of the nature and conditions of organic growth, as distinguished from other forms of growth, is likely to become more open to successful attack if the simpler cases are considered first.

By the term growth, as applied to ordinary physical objects, we usually mean simple increase in the quantity of some material forming a more or less definite system or aggregate; the system thus increases in size while retaining its special distinguishing properties or identity. Simple accretional growth are instances, *e. g.*, avalanches, stalactites, deltas, crystals. In the case of organic growth something additional and highly characteristic is involved. Growth is not the result of simple accumulation of materials already existing as such in the environment of the growing system; but the added material is chiefly of a kind not found in non-living nature and formed within the system itself through the specific chemical transformation of material taken from the surroundings. New chemical compounds are created in new and characteristic structural and other relationships. Part of the material thus synthesized, especially the protein and lipoid part, is built up to form the living and organized substratum of the growing cell or organism.

Such considerations show (incidentally) that the conception of organic development prevailing at one time, of an unfolding, increasing, or becoming evident of something already in existence or latent in the germ, is no longer a tenable one. The creation or new appearance of *novelty* seems to be an essential fact in most if not all natural occurrence; and this is notably the case in organic growth. To a modern biologist the epigenetic conception of development is the only one possible; new characters arise at each ontogenetic stage in correlation with the formation of new chemical compounds in new physical combinations.

In the case of inorganic growth, therefore, we should expect to find the closest resemblances to organic growth in those growing

systems where growth is dependent on the chemical transformation of material incorporated from the surroundings, followed by deposition of the more permanent reaction-products within the growing system. It is well known how a crystal in a supersaturated solution increases in size while retaining definite form; the packing or mutual apposition of molecules similar in their shape and size and with their axes parallel explains the regularity in the structure of the whole resulting system; similarly an ice-crystal in subcooled water forms the center of deposition for further ice-crystals. In both of these cases material taken from the surroundings is transformed and deposited to build up a definite solid structure, but the transformation is physical rather than chemical. On the other hand in such examples of inorganic growth as the extension of a rust spot on a sheet of iron immersed in water, or the formation of "lead trees," the new material is formed by chemical transformation.

Inorganic growths dependent on such "germ-actions" often closely simulate organic forms; the frost patterns on window panes are a beautiful example; in this case the ice crystals are formed in apposition to one another and an apical growth results. The hexagonal crystal system of water is favorable to the formation of delicately branching arrangements; the characteristic "twinning," well seen in snow-flakes, also contributes to this result. The already formed crystal structure determines the formation of further crystalline deposit of the same kind, the apices or projecting angles of the structure forming the regions of most rapid deposition. In this manner long rows of crystal structure with lateral branches are built up by the opposition of new crystals at the extremities of the crystal-pattern already laid down. The resemblance to plant-growth depends on this peculiarity; a terminal or apical habit of growth is common to growing stems, leaves, roots and other plant organs, and determines the final structure of the whole system.

In the formation of tin-trees or lead-trees the form adopted by the growing system depends on a similar apical process of deposition, but in this case special electro-chemical factors enter. When a piece of zinc is placed in a solution of a lead salt, the zinc dissolves as Zn ions, and metallic lead separates out simultaneously; by continuation of this process there is built up by degrees a characteristic tree-like or branching structure. Each portion of lead as it is deposited forms a cathode in the zinc-lead couple; and hence more and more lead is separated from solution by a process of local electrolysis. The new metal is deposited in crystalline form and most rapidly at the apical regions, hence the deposit extends in a branching manner. A similar tendency to a branching

or arborescent form of deposit is not infrequent in the electrolytic separation of metals at cathodes.

Closer analogies to organic growths are seen in the precipitation-structures formed from metals immersed in solutions of salts whose anions form insoluble compounds with the metals; structures are built up of a tubular or quasi-cellular structure with semi-permeable membranes for walls; and the resemblance both in appearance and conditions of formation to certain types of plant growth is in many respects surprisingly close. These structures are related to those investigated by Leduc and Herrera, and formed by introducing crystals or solutions of alkali-earth and heavy metal salts into solutions which form precipitation-membranes with the introduced salt. The growths obtained by placing copper sulphate in ferrocyanide solutions are good examples. Leduc's book, "the Mechanism of Life," gives a fascinating account of these phenomena. The growths formed from metals are, however, peculiar in the fact that the structure-forming precipitate is deposited as the result of local electrolysis at the metallic surface; the presence of this electric factor thus renders these inorganic growths amenable to electric control (acceleration, retardation, directive influence), and this feature gives them an additional interest as models of organic growth-processes.

The methods of producing these growths are very simple. When a piece of iron wire is placed in a solution of potassium ferricyanide (2 to 4 per cent.), containing some egg-white or gelatine to act as protective colloid and a little sodium chloride, delicate blue-green vesicles and tubules of ferrous ferricyanide are quickly formed; the tubules grow out rapidly into the solution, and within half an hour or less the whole wire is covered with a dense filamentous growth resembling blue-green algae. Iron is an especially favorable metal for such experiments, apparently because of the presence of numerous local electric couples between different areas of the metallic surface, and filaments several centimeters long are readily obtained. These often exhibit delicate and regular cross-striations and other appearances suggestive of organic structure. If instead of iron the related metals, cobalt and nickel, are used, a different type of growth is obtained, coarser and more vesicular in structure and with finer tubules; many of the latter follow a characteristic tortuous or zig-zag course. To produce rapid growth with these metals it is necessary to accelerate the reaction by the contact of a nobler metal, *e. g.*, copper or platinum; a copper wire wound about one end of a strip of nickel (or cobalt) greatly promotes the growth of precipitation-structures. This effect, which

may be regarded as a kind of catalytic action, depends on the formation of a local couple, the nickel becoming anode and hence sending ions more rapidly into the solution; the accelerating influence of the copper is perceptible for some centimeters from the contact. Zinc and cadmium, another pair of closely related metals, also readily form highly characteristic vesicles and tubules, which frequently give rise to compound structures of quite remarkable beauty and symmetry, especially with zinc. Here also the contact of a nobler metal is necessary for rapid growth; the same effect may be produced by carbon, *e. g.*, by marking the strip of zinc with lead pencil. In all such experiments the growth is most rapid near the catalyzing metal or carbon, and a gradient in rate of growth is seen extending for several centimeters from the contact. Copper wires in contact with carbon or platinum also produce characteristic growths. Each metal in fact forms a definite type of precipitation-structure, having morphological characters which are specific for that metal; and it is interesting to note that the structures formed from closely related metals, *e. g.*, zinc and cadmium, or cobalt and nickel, resemble each other more closely in certain characteristic structural details (*e. g.*, the zig-zag tubules of cobalt and nickel) than when the chemical relationship is more distant. Something analogous to family resemblance is seen in such cases. In organisms also morphological similarity and chemical similarity are closely associated.

The resemblances between organic growths and precipitation-growths are of a general rather than particular kind, and too much emphasis should not be laid on superficial points of agreement. Yet when we consider the broad features of the transformative activity in the two cases and its fundamental determining and controlling conditions, certain identities appear which indicate that organic growth processes are largely conditioned by general factors of the same kind as those present in the above inorganic systems. In both cases the specific features of growth are referable to the specific peculiarities in the chemical composition of the structural material. We find that in the precipitation-growths a slight variation in chemical composition, *e. g.*, the substitution of cadmium for zinc, makes a definite change in the kind of structure developed; similarly it is possible that in organic growth a slight variation in the chemical composition of a structural protein, such as the substitution of one amino acid for another in the chain, may modify definitely the physical or other properties of the newly formed structure. One might suggest that the appearance of a sudden variation or mutation in an organism is the result of a chemical change of this kind. The formation of a new compound in forma-

tive metabolism may thus mean the appearance of a new structural and physiological character.[5]

But it is with respect to the problem of correlation, of the mutual influence exerted upon one another by growing parts of the same organism, that the metallic model shows perhaps its most striking resemblances to the growing and developing organism. We describe this phenomenon in organisms by saying, for example, that the growth of one region *inhibits* the growth of another, usually adjoining, region. Why it should do so is the problem. Why should a single blastomere of the 2-cell stage give rise to a half organism when the other blastomere develops by its side, but a whole organism when it develops in isolation? Or a plant bud begin growing only after an adjacent growing bud is removed or ceases active growth? Evidently some physiological influence of a repressive or inhibitory kind is exerted through a distance, and in at least some cases this influence can be shown to be independent of direct transfer of material between the two regions concerned. Such facts suggest that this type of control, like other forms of chemical control at a distance, may be electrical in nature. Is it possible that the bioelectric currents, always present in living organisms, influence the chemical processes underlying organic growth? Currents arising in association with the metabolic processes in a rapidly growing region might then control growth processes at a distance from this region, just as the electric currents in the iron-zinc-ferricyanide system control the formation of precipitation-tubules by one metal at a distance from the other.

The inhibiting influence exerted by an actively growing part of an organism upon the growth of adjacent parts is a phenomenon of too general occurrence to be referred to special conditions peculiar to any one organism or group of organisms. Its basis is apparently some physiological condition common to all organisms. The transport of growth-inhibiting substances is clearly not the condition in such well-known effects as the prevention of the growth of axillary buds in seedlings by the growth of the terminal bud. Recent experiments have shown that we can prevent the inhibitory influence from passing by conditions that do not interfere with the transport of material along the stem.[6] If the inhibitory influence is not due to transport, to what is it due?

[5] If closely related species can be distinguished by precipitin or anaphylaxis tests, it is probable that mutants can similarly be distinguished from their parent organisms, although apparently no experiments of this kind have been tried. Leo Loeb finds evidence that there even exists a chemical differential between individuals of the same species (*cf. Amer. Naturalist*, 1920(Vol. 54, pp. 45, 55).

[6] *Cf.* Child and Bellamy, *Science*, 1919, Vol. 50, p. 362; *Botan. Gazette*, 1920, Vol. 70, p. 249; E. N. Harvey, *Amer. Naturalist*, 1920, Vol. 54, p. 362.

We cannot answer this question fully at present, but it is perhaps sufficient to point out that the fundamental problem involved is the general problem of the transmission of physiological influence in living protoplasm. Through what means does a physiological process occurring at one region affect processes at other regions? If we leave out of consideration the numerous instances where the mechanism of physiological correlation is evidently of a transportative kind, as seen in the effects of the various growth-determining hormones (thyroid, pituitary, ovary, etc.,) or of the hormones determining glandular secretion or rate of respiration, we have remaining a large class of effects highly characteristic of living matter in all of its forms, namely, those transmissions of local states of activity or excitation known generally as protoplasmic transmissions. Sherrington points out that in higher animals there exist two chief methods by which the various chemical and physiological activities are integrated or made to work in harmony, namely (1) integration by transport of chemical substances (usually special metabolic products) from region to region, chiefly in the blood stream, and (2) integration by transmission of physiological influence, excitatory and inhibitory, to a distance through the living protoplasm without material transport between the regions; the chief example of this type of process is nervous transmission. The nervous system is the chief integrating and coordinating system in higher animals; nervous transmission, however, is merely a specialized form of a type of transmission present everywhere in protoplasm. If the metabolic processes underlying (*e. g.*) muscular contraction can be thus controlled at a distance, it is not difficult to believe that those underlying growth can be similarly controlled. This mode of influence has been called physiological distance-action, after the analogy of chemical distance-action, and our problem is to determine its physico-chemical nature. One of its most characteristic manifestations is seen in the transmission of growth-inhibiting and other formative and correlating influence in growing and developing organisms.

For our purpose the most instructive instances are those in which the growth of one region controls that of an adjoining region. How can a growing bud on a piece of stem in a Bryophyllum prevent the growth of roots or shoots on an attached leaf,[7] or one growing axis inhibit another in the blastodisc of a Fundulus egg,[8] unless there is transfer of inhibiting substances from the actively growing to the inhibited area? or unless the actively growing region appropriates all of the available nutriment? Yet both of

[7] J. Loeb, *Botan. Gazette*, 1915, Vol. 60, p. 253.

[8] C. R. Stockard, *Amer. Journ. Anatomy*, 1921, Vol. 28, p. 115.

these modes of explanation are apparently inapplicable in many cases. The only general physical conception which seems to me to throw some light on this and related problems is the one which regards physiological distance-action as a special case of the phenomenon called by Ostwald "chemical distance-action," and well known to all students of electrochemistry. By this term is meant the influence which the chemical reaction at one electrode-area of a circuit exerts upon those at the other electrode-area. This influence has a reciprocal character, dependent ultimately on the fact that the flow of electricity around the circuit is in one direction; hence oxidation at one electrode is associated with the reverse process, reduction, at the other. According to Faraday's law the rates of the two opposite electrochemical reactions must be equal, hence variation in the one involves a corresponding variation in the other. The above precipitation-growths from metals furnish many striking examples of this influence; the contact of a piece of zinc with an iron wire immersed in a ferricyanide solution prevents the outgrowth of precipitation-filaments from the iron, even at a distance of several centimeters from the contact; at the same time their formation from the zinc is promoted. In this case it is not possible to assume that inhibitory substances are derived from the zinc, where growth of filaments is rapid, and transported to the iron. Yet there is a definite influence, exerted through a distance, which inhibits the outgrowth of precipitation-filaments from the iron so long as they are being rapidly formed from the zinc. This influence is electrical and depends simply on the passage of the electric current around the circuit constituted by the two metals and the salt solution. Metallic zinc in contact with the solution is electrically negative or anodic; the zinc ions given off to the solution form the precipitate of zinc ferricyanide which builds up the filaments. The iron is cathodic, *i. e.*, the positive current is in the direction from solution to metal, thus preventing the passage of iron ions into solution; hence no precipitate forms. If, however, we sever the iron wire from metallic connection with the zinc, *e. g.*, by cutting off its projecting extremity, the isolated portion at once develops filaments. The compensating or inhibiting condition is removed when the electrical circuit between the two metals is broken.

In cases of regeneration in animals or plants the removal of a portion of the organism frequently initiates an extensive process of growth and development at the cut surface. We may infer therefore that many stationary or quiescent regions of the organism are capable of active growth or proliferation, but do not manifest this power until they are removed from the influence of other

regions. Is it possible that in such cases what prevents growth is the passage of electric currents between regions of different growth-activity, the more active regions—which are those of greater metabolic or synthetic activity—inhibiting the less active through the currents associated with their growth?

There are many facts which point in this direction. Hermann and Müller-Hettlingen found that in seedlings the regions near the actively growing zones—terminal buds or root-tips—were negative relatively to those near the cotyledons;[9] regenerating hydranth heads are negative to the stems;[10] the growing zones in planarians and annelids are negative to intermediate regions.[11] Further studies in this field are desirable, but all of the evidence now available agrees in indicating that regions where growth and cell-division are active are in general negative to inactive regions—negative, that is, in the same sense as the stimulated region of a muscle or nerve is negative to the unstimulated. The regions where the positive stream of the bioelectric circuit enters the living system from the surrounding medium are the regions of most active growth; those where it leaves are the quiescent or less active regions. The physiological or metabolic asymmetry is associated with an electrical assymmetry or potential difference. Such actively growing regions, in addition to their electro-negativity, show in general a higher oxygen-consumption and carbon-dioxide output and a greater susceptibility to poisons than less active regions. A connection between the metabolic processes underlying growth and the bioelectric currents is thus indicated. In plants removal of oxygen has been shown to abolish these currents, a fact indicating that oxidation-processes are concerned in their production.

If the bioelectric currents have a direct influence on growth, we should expect that electric currents led into the growing systems from outside sources would have a similar influence. Regions where the positive stream enters the growing system from the surroundings should be favorably influenced in their growth, since such regions correspond to the "negative" regions in the bioelectric circuits of growing organisms; these regions, as just shown, are those of most rapid growth. Recently it has been found by Lund that regeneration of new polyps from the cut stems of the hydroid Obelia may be experimentally controlled by weak electric currents passing lengthwise through the stem; the formation of hydranths is promoted where the current passes so as to enter the stem, *i. e.*, at the cut end facing the anode, and inhibited at the

[9] *Pflüger's Archiv.*, 1883, Vol. 31, p. 193.
[10] A. P. Mathews, *Amer. Journ. Physiol.*, 1903, Vol. 8, p. 294.
[11] *Cf.* C. M. Child, *Biol. Bulletin*, 1921, Vol. 41, p. 90.

other end. A polar influence on formative processes, corresponding to that on stimulation processes, is thus shown.[12] These interesting observations agree with those of the Indian investigator, Bose, who finds that the electric current influences growth-movements in higher plants in a polar manner, the anode enhancing and the cathode depressing the normal rate;[13] and also with the recent experiments of Sven Ingvar in the Yale laboratory, which have shown that weak constant currents exert a directive influence on the outgrowth of the processes from embryonic nerve cells; here also a polar influence is seen, the processes growing toward the anode being morphologically different from those growing toward the cathode.[14]

If the growth processes in living organisms are thus subject to artificial electrical control, it seems reasonable to infer that the natural or physiological methods of control in normal growth and development are also in large part electrical. The bioelectric currents would thus become essential formative factors, just as they are essential factors in excitation and transmission; organic polarity, as Mathews suggested, would become electrical polarity. This, however, would again be referred to chemical polarity, since we must assume that the bioelectric currents, like the currents in metallic couples or other current-yielding systems (where the energy of the current is derived from chemical reactions at surfaces) are the expression or accompaniment of chemical processes in the living system. The metabolic processes underlying growth are of complex and largely unanalyzed nature, but we know that they are typically associated with the consumption of oxygen and include specific syntheses by which the new structure-forming compounds are built up. Can we then say that the chief method of construction of such compounds is electro-synthesis? Such a characterization may not in itself add much to our knowledge, but it suggests directions in which research may be profitable. It implies, especially, that the basis of all such effects, like the basis of other manifestations of irritability, is to be sought in the conditions determining the electrical sensitivity of living matter, one of its most fundamental characteristics. This in turn is almost certainly conditioned by the polyphasic and film-pervaded structure of the protoplasmic system.[15]

12 E. J. Lund, *Journ. Exper. Zoology*, 1921, Vol. 34, p. 471.

13 J. C. Bose, *Proc. Roy. Soc.*, B. 1918, Vol. 90, p. 364

14 S. Ingvar, *Proc. Soc. Exper. Biol. and Medicine*, N. Y., 1920, Vol. 17, p. 198.

15 *Cf.* my discussion of the basis of protoplasmic irritability and transmission in The Scientific Monthly, 1919, Vol. 8, pp. 457 and 552.

MENTAL AND PHYSICAL EFFECTS OF FRESH AIR

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BILL NYE'S History of the United States shows two drawings which compare the Indian women of fancy with the Indian women of fact. It is a pity that Nye did not think of cartooning the ventilation of fancy and the ventilation of fact. After the customary school instruction plus a deep draught of tradition we were caught unawares by a recent article in THE SCIENTIFIC MONTHLY asserting that human life could continue in the same room with oxygen-consuming plants. Perhaps some one will yet have the temerity to assert that the nostrils were made smaller than the mouth to prevent the breathing of all out-of-doors at one gasp, thus suffocating ourselves with too much fresh air. Is fresh air really essential? Are mental and physical prosperity greatest in 100 per cent. fresh air? Is it open air that human nature craves or is the primeval association of open air?

What is man's attitude toward the open air, as shown in the history of the race? Back somewhere in the time when man dwelt in the "well ventilated arboreal tenements" of the tree tops, some individuals, finding more to interest them on the ground, moved down from their leafy heights, and learned to walk upright. Beset, however, by countless enemies, he was compelled to seek some shelter, and so began the life in caves which has persisted ever since. Deserting the forests for more open country, man found his original covering of hair inadequate, and betook himself to clothing, the second step in the complete enclosure of his body.

Officially, man was a troglodyte, or cave dweller, up to a recent era in his history. As an actual, but unadmitted, fact, he is one yet. The ancient cliff-dwellers in their caves, and the more modern Moqui in his pueblo, are not so very different from the up-to-date apartment-house denizen, or shall we say, inmate. It does seem as though man for ages past had thriven in a completely enclosed state. Even in the matter of clothing to this day we go about protected to the utmost, the only exceptions being the rags of poverty and vice versa.

Ventilation has been for eons either unknown or unheeded. In

most cases entirely different considerations have fixed the construction of the buildings in which humans pass a great part of their time. In northern lands, for defense against cold, the Eskimos build their igloos, and the Lapps their huts, with one undersized door as the only opening. Many other examples are familiar. Ventilation as we know it, is truly a modern notion. In 1660, Sir Christopher Wren devised a crude system of ventilation for the Parliament Buildings in London, seemingly the first official recognition of the idea; but the spread of the idea has taken many years. In fact, those of us who have visited the halls of our own congress, will agree that those halls are to this day ventilated solely by the newspapers. The old four-poster bed, with its heavy canopy and impermeable curtains, is a commonplace of a day not far gone. It is but yesterday since we kept our windows shut at night, for fear of some poisonous "miasma" in the night air.

The modern preference for open windows, open-air schools and so on is due to one or the other of the following causes; either the desired sensation of being different from our fathers and mothers or the realization of some actual benefit to be derived from the new order of things. Let us see, then, what sort of opinions are actually held about the conditions which fix the desirability of the kind of air with which we surround ourselves.

Mr. Ellsworth Huntington, in a 1915 publication of the Yale University Press, says:

> To-day a certain peculiar type of climate prevails wherever civilization is high. In the past, the same type seems to have prevailed wherever a great civilization arose. Therefore, such a climate seems to be a necessary condition of great progress.

The foregoing, part of an attempt to show the part played by climate in human development, is unfortunate, for a moment's thought will show that while each particular civilization may have its peculiar climate, these respective climates differed more widely than the civilizations they represented. Ancient Egypt, a country of great heat and dryness, is rated as a civilization, along with ancient Greece, with its temperate climate and adequate rainfall. A high civilization arose in Rome and along the warm, sunny slopes of Italy, but this fact proves nothing against the greatness of fog-visited Britain. In New York City, a more or less active hive of human effort, both extremes and all possible means of climate are experienced from one day to the next!

It is an acknowledged fact that warm air makes us sleepy. It is equally undisputed that we find it difficult to sleep on a warm night. When we suffer from certain ailments, our doctors, recommending a change of climate, send us to Colorado, Arizona, or

some place with an equally dry atmosphere. Yet we have authorities who regard dry air with dread. Watt, in 1910, wrote as follows:

> Insanity grows on those who live in hot, dry air, do exasperating work, and feel abused. . . . Men are breaking down in business by too much attention to it, they think. The real trouble is, they are conducting their business in hot, dry rooms during the cold months of the year.

The same writer gives dryness as a cause of the falling-off in church attendance. It is to be hoped that the increased "dryness" to which the country is being subjected, will have the opposite effect. We are used to regarding dampness of air or climate as an unhealthful condition, but dryness seems to be just as bad, in the opinion of many. Early writers went to great extremes in both directions, attributing to air conditions all sorts of things, "from the color of a man's skin and the contour of his face, to the prevalence of religious ideas, and the (supposed) fact that more twins are born in Egypt than elsewhere," to quote from Stecher, in "The Effect of Humidity on General Efficiency."

Popular opinion is an excellent way to give permanence to prejudice. Bliss claims that so thoroughly has the fresh-air taken hold of many, that neither facts nor figures to the contrary are of the slightest interest. A remarkable example of this is found in the description of an experiment made in 1913-14 by D. C. Bliss, superintendent of schools of Montclair, N. J. He says:

> A surprising feature of the whole experiment with the open-window classes is the attitude of the parents. Almost without exception they are convinced that their own children benefited greatly by the plan. This conviction is so positive that it is not affected in the least by the statistics of the classes.

These statistics, which showed a slight balance against the open-window classes, will be referred to later.

Many of us, then, believe that for health, atmospheric conditions should be thus and so. Clearly, however, a consideration of opinion from all sources shows about half of us in favor of "thus," and the rest of us firm believers in "so." In other words, public opinion, the strongest of forces in a discussion like this, is at the same time the least reliable. With the two camps of believers arranged back to back, it is at least possible that one is in the right, but opinion itself furnishes no safe ground for judgment. That opinion will often unconsciously pervert fact to serve its own ends was rather amusingly shown by press and other comments on an address recently made by the writer before the International Conference of Women Physicians. The newspaper writers took just enough actual words from the address to make some humorous reading which had no especial connection with the

speaker's meaning. A telegram was received from an association in a small city, asking for a statement of the speaker's true position. He replied that he was in favor of rightly controlled open-air schools *for experimental purposes.* The secretary of the association wrote back, much pleased with the speaker's "implied permission to quote you as favoring a rightly controlled open-air school." Using the same words, nearly, but with a vast difference in meaning, this little episode illustrates perfectly what might be called "auto-interpretation."

Since children are probably more sensitive to environmental conditions perhaps the best way to study the effects of fresh air *versus* various degrees of non-fresh air is to investigate experience and experiments with open-air, open-window, and otherwise fresh-air schools. The first open-air school was opened in the woods at Charlottenburg, a suburb of Berlin, and soon spread all over Germany. Not long afterward, the first English open-air school was opened at Bostall Wood, near London. Then came the Bradford School, since which many others have been established in England. The first open-air school in the United States was at Providence, R. I.; we now have them all over the United States. There are some in Boston; there is one on the roof of the Horace Mann School at Teachers' College, Columbia University; there are some on abandoned New York City ferry boats. There are specially endowed schools of this open-air type in Chicago. Hence comes the argument that the schools must be satisfactory, because they have spread so rapidly.

Secondly, we have no record of a single open-air school which has been abandoned; another argument worth noting.

Third, every account, except one, gives most glowing descriptions of the success of this work.

Fourth, children gain rapidly in weight. Here is a sample from one of the open-air schools. In two and one half months the children in this school gained 3.6 pounds on the average, whereas the children in the ordinary schools gained but one pound on the average.

The fifth proof is that the open-air schools have considerable therapeutic value. Here are some figures from some of the German schools. Of thirty-four children who were anemic, after being in the open-air schools for some time, one case was aggravated, nine were unchanged, eleven were improved and thirteen cured. Of 38 cases of scrofula, none was aggravated, eight were unchanged, 22 were improved and eight cured. Of 14 cases of heart-disease, none was aggravated, seven unchanged, seven improved and none cured. Of 21 cases of pulmonary disease, one was aggravated,

eight were unchanged, eight were improved, and four were cured. This makes a total of 107 children that were studied; of which number but two were aggravated, 32 were unchanged, 38 improved and 25 cured.

Next, there comes the claim from England and Germany that education is twice as efficient, in the sense that the pupils spend but half their time on regular school work, and still keep up with their corresponding grades in the ordinary schools.

A number of other claims are made, such as increased happiness of the children; improvement in attendance; and one statement is made that truthfulness rose several degrees!

A critical inspection of these claims reveals that they are largely claims and nothing more. They may be true, they may not be true. Open-air schools are such a radical departure that their very novelty appeals to radicals and enthusiasts. This alone might account for the rapid spread of the idea.

The claim that education in open-air schools is twice as efficient does not appear to have been checked by objective tests. Subjective estimates of mental changes are known to be extremely unreliable, particularly when made by interested though honest individuals.

The increase in attendance recorded for the open-air schools, it must be said, took place entirely during those months of the year when the weather is at its best. This is typical of most of the arguments advanced; they are not checked against certain other possible explanations of the results besides the presence of fresh air.

Here is a typical day for the pupils in the ordinary school, which may be compared with the typical day of the open-air school scholars. In the ordinary school, the pupils spend all their time during the best part of the day, that is, from nine to twelve o'clock and from one o'clock to three, in the classroom. The medical, dental and optical care they receive from the school authorities is inadequate to put it as charitably as possible, and they receive little other attention aside from their regular lessons. Here is the program of the open-air school for a day. Reports state that the enthusiastic cooperation of the best dentists, physicians and oculists in town is readily secured, so that the children are constantly receiving better attention than they would in their own homes. At eight a. m., an hour before the ordinary schools begin, the open-air pupils are served with hot soup, bread and butter. After every half-hour, they have vigorous exercise. At ten a. m. they have two glasses of milk, bread and butter. At 12:30 they have a good dinner, followed by sleep. At 4 p. m. there is milk, rye bread and jam. At 7 p. m.—notice how late—the pupils are given a good supper, and sent home. Of course, the regular les-

sons are given in the intervals between the items noted above. The program outlined is actually followed in many schools, and all adhere to a similar schedule in greater or less degree.

We find in one of the glowing descriptions of these schools the following unintentional admission—quoted exactly:

"There is unanimous agreement that if children are to be benefited by open air, they must be well-fed." This statement is typical of the weak points in the arguments thus far given: Is it fresh air that produces the results, or is it superior feeding and physical care; and would it be possible to produce the same effect in the ordinary schools, by an equally increased care? The arguments do not tell us.

What light do carefully-controlled researches throw upon this whole question? Experimental results tend to show that mental activity, obviously one of the main factors in education, is not readily subject to outside influences. Poffenberger, administering strychnine in moderate doses, noted that no effect was produced on the mental powers of his subjects. Hollingworth reached the same conclusion with regard to caffein in the proportions found in coffee and certain other beverages. Results are not yet available from the national experiment conducted to discover the effect of reducing the national percentage of alcohol to 2.75. On the whole, mentality appears to be a peculiarly well insulated function. The writer after years as a teacher, has found the insulation impenetrable in many cases.

But there are experiments dealing with open-air directly. A study was made by Norsworthy, Hillegas, McCall and others at the Horace Mann School, New York City. On the roof of the building were constructed two classrooms, each having its southern side completely open, and large windows in its other sides and roof. Provision was made to shield books and blackboard from the direct glare of the sun, but otherwise the children were exposed to sunshine and air. The southern exposure could be closed off by a canvas cover during a driving rain. A playground was provided on the adjoining roof.

The open-air test was begun with a third grade and a fourth grade class. After the first year a fifth grade class was held in a room in the building below, this room having its windows open wide at all times. There were throughout the test several control classes in ordinary indoor classrooms, for purposes of comparison. The test continued through the four school years from 1912 to 1916. Psychological tests were made in each December and May by Norsworthy and Hillegas. At the same time, Dr. H. B. Keyes gave each child a thorough physical examination. There were

eight of the psychological tests given each time. The scores of these tests were summarized into a combined score for the four years. This result showed a small, but real, balance in favor of the open-air classes. This was also true for the physical tests for the first year, those for the other three years not being available. We must accept these results, however, with proper caution, because of the possibility that other factors than those tested were responsible for the result. The children who made up the open-air group were selected from those having physical or nervous weaknesses or tendencies. There were extra lunches and frequent outdoor play; these were denied the indoor classes, which might have had them about as well as the outdoor pupils. In any case, we must be careful about comparing the performances of more or less incomparable groups.

Consider now the experiment conducted by D. C. Bliss, superintendent of schools of Montclair, N. J., to determine the possible advantage of open-window classes. In this experiment, the same types of children were selected for both open-window and control classes. One class each from the second, third and fifth grades, were selected for the open-window group, each grade being located in a different building, and each checked by a control class of the same grade and size in the same building but under indoor conditions. During the cold months, the open-window groups were well wrapped, and protected against strong drafts, though their classrooms were maintained at a temperature of 50 degrees Fahrenheit. During the experiment, the open-window pupils were provided with light forenoon lunches at the parents' expense.

The tests measured three items: degree of nutrition, measured by fluctuations in weight; general health, indicated by attendance; and mental condition, shown by simple tests given twice each day.

A summary of Bliss's results shows no difference between the open-window and control groups in the psychological tests, and a small, but notable superiority in health for the control groups. In the previous year, an experiment had been made in which the open-window class was unprovided with the special lunch, and the room-temperature allowed to go as low as it would. Under these conditions, the health of the open-window classes showed up even less favorably.

Whatever our previous idea, then, the contradictory results of the two experiments cited should give us pause. More information is evidently needed. To this end, we ought to note the interesting and expertly directed experiment made by the New York State Commission on Ventilation, to determine the effect on mental

work, of recirculated air versus plenty of fresh air. The Board of Education of New York City permitted the commission to fit up especially for the test a couple of rooms in a school building that was in the course of erection. Hence the desired air conditions could be perfectly maintained. In one room, ventilating ducts provided a continuous influx of fresh air, the used air being drawn out. In the other room, the used air was drawn out, washed, and sent back again, so that the greater part of the air in the second room was used over and over. Only enough fresh air was introduced to prevent noticeable odor. The washing took out the dust, and probably the germs and some, at least, of the carbon-dioxide. Even so the CO_2 content of the air in the recirculating room was always much higher than in the fresh-air room, occasionally rising to twice as much. In both rooms, the purity of the air and the steam used by the heating-plant were constantly noted. A standard comfortable temperature of 68° and humidity of 50 per cent. were maintained in both the experimental and control rooms.

The experiment lasted from February to June of one year, and to make conclusions doubly reliable was repeated during the following school year. An unusually elaborate series of educational, psychological and physical measurements were made. The directors of these experiments were national authorities in their respective fields of education, psychology, medicine, physiology, sanitation, physics and engineering. No technique that these scientists could devise was omitted. Every effort was made to make the conclusion from these experiments final. What was the conclusion? The results from all the educational and psychological measurements when carefully summarized, showed roughly two per cent. greater progress and achievement for the pupils who were in the partly fresh air. The results from the medical measurements substantially agreed with those from the mental measurements, and the second experiment agreed with the first.

In addition to having no demonstrable deleterious mental or physical effects, the recirculation plan required only half the coal for heating that was needed for the fresh-air room. This enormous saving, widely applied, would buy for children many things of known mental and physical worth.

Glancing back over the propaganda for and against open-air schools we are tempted to paraphrase Pinckney: "Millions for defense but not one cent for" . . . . *the truth.* There has never been a really valid experiment to show whether open-air schools are desirable or undesirable. It is undoubtedly true that anemic pupils in open-air schools have more rapidly improved in weight,

health, hemoglobin and the like, but the thinnest readers of this article have a good chance of growing fat and hemogloby on the sanitary and feeding schedule of the best open-air schools! Personally we are inclined to favor open-air schools, not for the surplus of fresh air but because that seems to be the only way to secure for a few pupils a scientific attention which should be the privilege of all pupils. But such a policy is altogether too much like the Chinaman who burned his house to roast his pig.

Not even the admirable experiments of the New York State Commission on Ventilation tell us whether open-air schools are or are not advisable. Open- air schools usually bring sunshine to their pupils as well as fresh air. Furthermore the Ventilation Commission's experiments used typical pupils as subjects. Though it does not appear probable, it may be that anemic and diseased pupils prosper better on fresh air than normal pupils. But as matters now stand undiluted fresh air for children is on the defensive. The only trustworthy experiments to date have gone against absolute fresh air. Verily we are by nature Cave Dwellers still!

PROGRESS OF PUBLIC HEALTH WORK

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PUBLIC health work is as old as history. Among the ancients a part of it was purposeful; a part without intention,—both were valuable in the preservation of mankind.

The Egyptians filtered the muddy water of the Nile which rendered it potable, and in a measure prevented the spread of disease. Their custom of mummifying the dead by keeping them in brine for seventy days, then drying and placing them in tombs in the hills above the over-flow of the Nile was not without sanitary significance. They had rules concerning meat inspection, bathing, clothing, diet, and care of infants. Joseph's Well near the pyramid of Gizeh was excavated through solid rock for 297 feet, and is an excellent example of their efforts to obtain pure water.

The ruins of antiquity show that large reservoirs were common in ancient times. It is well known that the Chinese, for thousands of years, have used alum as a coagulant in the clarification of muddy water. The inhabitants of India, over 4,000 years ago, knew, "It is good to keep water in copper vessels, to expose it to sunlight, and to filter it through charcoal."

The Hebrews were the founders of public health work. Their methods were influenced by the practices of the nations that lived in the valleys of the Tigris and Euphrates, and probably by Persia. The Apostle Luke, a physician, says, "Moses was learned in all the wisdom of the Egyptians." The Hebrews obtained excellent results in wholesome living by making hygiene a part of their religion. The high priests were sanitary police. Their mandates covered diet, the touching of unclean objects, prevention of contagious disease, isolation, disinfection, sanitary inspection, removal of nuisances, certain industrial practices, personal hygiene, and medical jurisprudence.

The teachings of the Greek philosophers and physicians contained principles which promoted the well-being of the people as a whole. The laws of Solon and Lycurgus were especially helpful in improving the health of the masses. The Spartan requirements for warriors, the Olympic games and the emphasis placed upon the winning of distinction in them, together with the prominence given

to physical perfection in sculpture, art and literature inspired the youth to maintain a high degree of health.

The Romans were among the first of the ancients to provide methods for good ventilation of houses. Cremation, systems of drains and public baths were important contributions to sanitation and hygiene. The cloacae of the Romans were the forerunners of our sewerage systems. The great aqueducta, which brought fresh mountain water to Rome, played an important part in the prevention of epidemics. Their analogues are found today in the water supply of New York which has its source in the Catskills and is carried to the city by the Croton and Catskill aqueducts.

The Crusades, mis-rule, and innumerable wars prepared the soil and sowed the seed of the great epidemics in the middle ages which threatened man with extinction and gave the fatal thrust to tottering civilizations. Crowded conditions, the bad sanitation of the walled medieval towns, and gross immorality were the great predisposing factors. Gorton tells us that as late as the 16th century the English housewives swept the refuse from their dwellings into the streets. People seldom bathed or washed their clothes. Even eminent ecclesiastics swarmed with vermin. The garbage was emptied into unpaved streets and ground to mush when it rained. At nightfall shutters were opened and sewage poured into the streets.

The intellectuals of Rome, Alexandria and Constantinople were lost in a maze of theological controversy. Epidemics were regarded as a "visitation from God" inflicted alike upon the innocent and the guilty, to chasten a sinful world. As a result, no great effort was made to prevent them. Humanity escaped from the severe ravages of ergotism, scurvy, and influenza to be swept off by black death. Bubonic plague appeared in 1346 and killed sixty million people, over one-fourth of the earth's inhabitants. Plague visited London many times and would have depopulated it had not the people fled. Burning of the city killed the rats and reduced the plague. In 1495 syphilis appeared at the siege of Naples in epidemic form. In a few years, it had spread over the world,—a sad commentary on the morality of the time.

In the midst of the ravages of the plague, the first guardians of public health were appointed, and quarantine was attempted. It was tried in Venice and later extended to other Mediterranean ports, and to the North and Baltic seaboards. Health ordinances were promulgated and pest houses erected. During this period leprosy was at the height of its virulence and leprosaria were founded for the isolation of its victims. Each leper was compelled to carry a rattle, and to give notice of his presence by sounding

an alarm. The crude quarantine of the middle ages became the modern procedure based on scientific knowledge; the scavenger and the nuisance inspector specially trained live again in the expert sanitarians of today.

Although measures for the prevention of nuisances and for the imposition of quarantine were adopted in colonial days, as far back as 1647, it was not until 1849 that the State authorities began to consider seriously their duties in connection with public health. In May of this year the Governor of Massachusetts appointed a commission under Lemuel Shattuck to ascertain the health needs of the commonwealth and to make recommendations.

The Shattuck commission advised the establishment of a central Board of Health charged with the general execution of the health laws of the State, the creation of local Boards of Health, the taking of a census of the people, and a systematic registration of marriages, births and deaths. It recommended an investigation into the cause of disease, abatement of the smoke nuisance, adoption of means for public health education, and other far-reaching measures. The report of the committee to the legislature was pigeonholed for twenty years, but in 1869, the State Board of Health of Massachusetts began work under a broad charter, which has been the model for other states. In 1877 Illinois became the second state to establish a Board of Health.

Permanent governmental health organizations in the country came into existence to combat repeated outbreaks of cholera, typhus and yellow fevers. They were created when disease was supposed to have its origin in filth; when sewer gas and foul odors were thought to be the cause of epidemics and night air to carry illness and death.

Sanitation

Under the influence of the filth theory of disease, the efforts of public health officials were concentrated on the abatement of nuisances by scavenging, by constructing sewers, and by building water-closets. They enforced measures to prevent overcrowding, to insure better housing, to promote ventilation, and to provide for a supply of safe milk and of unpolluted water. Such was the nature of public health work until the decade of the 80's, when the rapid, brilliant discoveries of bacteriology, showing the relation of microorganisms to diseases, gave to the world a different conception of the cause of contagion.

The "sewer-gas-foul-odor-night-air era" of public health work was one of considerable progress. In their vigorous attempts to eliminate "emanations which polluted the air," sanitarians made great contributions to comfort, common decency, and public health.

We know now the safe disposal of sewage and the provision of pure water supplies were great factors in the eradication of cholera, and in the reduction of typhoid fever and the "diarrheas." Less crowded living conditions and cleaner houses did much to decrease vermin and louse-borne typhus fever. General cleanliness may have slightly diminished the incidence of disease spread by the secretions from the nose and throat. It had little effect upon the occurrence of yellow fever.

While the pioneers in public health did much for comfort, convenience, and civic betterment, their erroneous conception as to the cause of disease has remained an unhappy legacy to succeeding generations. There are many today who fail to distinguish between filth, contaminated with disease germs, and unsightly rubbish, in itself incapable of causing illness. Believers in sewer gas are not entirely extinct even among the medical profession. Emphasis upon air as a carrier of disease kept down bed-room windows and delayed the building of sleeping-porches for several generations. Fear of air-borne disease still causes a great waste of formaldehyde gas in fumigation which is often more effective in the production of psychic calm than in the destruction of pathogenic bacteria.

In 1893 Smith and Kilbourne brought to the attention of the world the role of the tick in the spread of Texas fever in cattle. Within a few years the relation of the mosquito to malaria and yellow fever, of the rat and the flea to plague, of the tsetse fly to African sleeping-sickness, and of the louse to typhus fever were shown. These discoveries of insect transmission of disease were of as far-reaching importance to the world as those of Copernicus, Columbus, or of Edison. Ross, Reed, Nicolle, Kitasato, McCoy and others showed insects to be the center of a system around which revolved the great pestilences which have scourged the race from antiquity. They did not discover unknown continents, but they made it possible to create a new world within the tropics. The practical use of their researches made the Panama Canal possible, saved the South from yellow fever, reduced disease and increased progress wherever the flea, louse, or mosquito are to be found.

The knowledge of the relation of insects to disease intensified sanitation. Stagnant pools were drained or filled, swamps ditched, rain barrels screened, and tin-cans destroyed to eliminate the breeding places of the yellow fever and malaria producing mosquito. In screening against the mosquito, the danger from the fly was reduced. To prevent plague, the rat was destroyed along with his fleas, to the great saving of food stuffs. Domestic sanitation and personal hygiene made new progress, as it became generally known that typhus fever was carried by the louse.

Isolation

Following the demonstration that communicable disease was due to specific micro-organisms, over-emphasis on the environment as the origin of disease gave way to control of man in preventing it. Rules and laws for the isolation of patients and carriers were enacted. Enforcement of these regulations gave rise to compulsory notification of communicable disease and the establishment of laboratories to ascertain the presence or absence of the specific bacteria. The length of incubation, the period of communicability, and the manner in which the disease is transmitted became the factors determining the length and nature of quarantine.

A great deal was expected from thorough isolation. Much was accomplished, but careful observation soon revealed that complete eradication of disease by this method was not to be realized. Isolation with bacteriological control, in all probability, will eliminate typhoid, paratyphoid, and the dysenteries. It has kept cholera beyond the seaboard, and in connection with sanitation, has made typhus fever a comparatively negligible disease in this country.

The failure of the discovery of the cause of chickenpox, smallpox, measles, German measles, and scarlet fever make it impossible to obtain the results first expected from isolation, because of the inability to recognize all cases before they have become communicable, and to determine with certainty the exact period at which they cease to be infectious. For a similar reason mild cases and carriers are missed. Scarlet fever and infantile paralysis present typical forms which are frequently overlooked. Whooping cough and mumps are often transmissible before symptoms are sufficiently developed for diagnosis.

In dealing with sputum-borne disease, isolation is very helpful, but often ineffective. The epidemic of poliomyelitis of 1916 taught health officers their inability to suppress it. It was stopped by the falling temperature of autumn rather than by the will of applied science. Influenza swept the world in 1918 and burned out before means could be found to control it. Meningitis exacted a deadly toll in the armies of both Europe and America; measles, complicated by pneumonia, proved one of the most fatal of diseases to soldiers in cantonments.

Experience with isolation in the prevention of disease has shown that to be effective it must be early. The failure to isolate promptly the first patient cannot be off-set by the most rigid quarantine of subsequent cases. Isolation has probably done a great deal to eliminate virulent strains of many communicable diseases since they are usually quickly recognized. "Every case of tuberculosis isolated means an average of three less new infections."

Group Practice

For centuries medical practice has been individual. The patient sent for the doctor, was cared for by him, and paid the bill. As little was known concerning the cause, method of spread, or means of prevention of disease, the physician had little responsibility to the community beyond the observing of a crude quarantine and the giving of an opinion as to the relation of nuisances to illness. The rapid advances in biology, chemistry and preventive medicine have shown the social and economic aspects of disease, and are rapidly changing medicine from being paramountly personal to predominantly public.

If a child should have infantile paralysis in a community, the public would insist upon it receiving every consideration essential to comfort and an early recovery, but the people would want to be sure that the case was so managed that other children would not lose their lives or be crippled for life. The citizens of any city would be greatly interested in a single case of Asiatic cholera occuring in their midst because it might prove the match for an explosive epidemic that would effect the lives of thousands and turn millions in trade from the channels of business.

As a result of this public appreciation of the importance of disease, there have arisen numerous agencies endeavoring to prevent accidents and illness in particular groups of individuals. These organizations are rendering a fine service in the education of the public, in the improvement of health, and in civic betterment, but they greatly need to be correlated, and to be given responsibility commensurate with their relative importance. It is essential for them to become a unified force for health in order to secure a synchronous attack upon disease with the best available methods.

Maternal and Child Welfare

The United States loses one mother for every 154 births, the highest rate of the seventeen principal countries of the world. Over 23,000 women died in 1918 on the altar of maternity, at least 50 percent. a needless sacrifice to poverty, ignorance, and inadequate medical and nursing attention. The United States stands eleventh in infant mortality, losing one in every ten during the first year of life, which is twice that of New Zealand, the lowest. In the United States a new born child has less chance of living a week than a man of ninety; of living a year than a man of eighty.

The great enemy of the mother and baby is poverty. The smaller the wage of the father, the poorer the family, the greater the hardships upon the mother, and the less the chance of the child to survive the first year. Income plays the chief role in locating the home and in determining its kind. Low income often sends the mother

to work, substitutes artificial for natural food, encourages bad housing, and promotes insanitary surroundings. Studies of infant mortality, made by the Children's Bureau in Waterbury, Connecticut, showed that children born in rear houses or in houses on alleys had a death rate of 172 per 1000; those located on the street, 120.6. In Manchester, New Hampshire, the rate was 123, where the number of persons averaged less than one per room, and 261.7 where they averaged more than two but less than three. The mortality for babies whose mothers were employed outside of the home was 312.9 per thousand while the rate was 122 for those whose mothers had no occupation but the care of their households.

From surveys in small cities, in rural districts, and in the large city of Baltimore, it was found that regardless of color, race, or nationality, the infant death rate varies inversely with the income of the father. When the father's income represents the ability to insure care and comfort ($1850 a year or more), the death rate was one-fourth as high as when the father's earnings fell into the lowest wage group ($450 or less).

Ignorance, as exhibited in the feeding and care of the infant, is an important factor in the death rate. It is not, however, limited to any one class of society, but operates most viciously in the group whose means of defense are most weakened by poverty. The mother, both ignorant and poverty stricken, is a menace because she is socially helpless unless the community or a philanthropist takes the responsibility of providing her adequate medical and nursing care, proper instruction in hygiene of maternity and of infancy, and decent housing.

Application of available knowledge will reduce maternal and infant mortality by 50 per cent.; possible 75 per cent. The great public health problem is to educate the individual to demand, and the community to supply the necessary protection for mothers and children by providing prenatal and postnatal clinics and maternity hospitals or wards in a general hospital. It is necessary to supervise rigidly the training of midwives, and to provide better education for medical students in obstetrics.

A comprehensive plan in maternal and child welfare must include teaching and practical demonstrations for mothers in the household arts essential to her welfare and to that of her child. Consultation centers or welfare clinics for children must provide for periodical examinations and instruction as to nutrition, health, exercise, and recreation. It must take into consideration the welfare of the defective, delinquent, and dependent children. It must conserve the rights of children in reference to person, labor, education, and law. It must guarantee the interest of the child will be paramount in marriage and divorce, and that it shall receive justice whether legitimate or illegitimate.

Rural Health Work

It is estimated for the country at large that for every composite group of 71 persons, one will die during the year; two will be in bed constantly; thirty will have impairment of health, ranging all the way from the person who is just able to be out of bed to the one not quite up to normal; twenty-five will be what we call healthy, while thirteen will have that vigor essential to rendering dynamic the inspiration of high ideals. This general average applied to the rural sections which contain 48.1 per cent. of the population of the country, makes it possible to visualize the problem of rural health work and its relation to the ability of the rural population to pursue its vocation effectively. As the rural population feeds and clothes the state and is the foundation upon which cities and industries are erected, its illness presents a striking phase of the economics of disease.

The problem of rural health work can be successfully approached only by education of the individual to appreciate the importance of disease and to adopt the methods necessary to prevent it. The most effective educational agency is an adequate county health organization directed by a full time health officer with a sufficient number of properly trained public health nurses, sanitary inspectors and clerical assistants to do the work.

The first duty of the organization is the education of the public in respect to hygiene and sanitation. To this end, lectures and demonstrations are given, pamphlets and folders distributed, and articles on live health topics are prepared for the county papers. Exhibits are arranged in the schools and at the county fairs. The assistance of the movie is obtained and cooperation is given to every organization in teaching the facts concerning health.

Another important function of the county health organization deals with the control and prevention of communicable disease. In cooperation with attending physicians, the county health officer enforces the quarantine regulations of the state, determines the sources of contagion, and in collaboration with the public health nurses, visits schools and homes; in cooperation with teachers and parents he institutes measures for prevention of disease, arranges for physical examinations of children, and advises as to corrective measures. The public health nurses carry out the follow-up work. The health officer ascertains the occurrence of tuberculosis in the county, adopts measures to prevent its spread, and arranges with local physicians to establish clinics for persons with suspicious symptoms of the disease.

As far as practical, each home in the county is visited by the health officer, and a survey made of the construction and use of

latrines, the safeguarding of the water supply, and the handling of milk. He inspects the screening and advises as to the means to be employed for the elimination of the breeding places of the fly and the mosquito. A nurse visits each house where bottle-fed children are suffering from digestive disturbances, and gives instruction to mothers in the essentials of home sanitation and infant care.

As only 56 per cent. of the 3,027 counties in the United States have hospitals, a number of the directors of county health organizations find it necessary to give considerable time to the creating of public sentiment favorable to the establishment of adequate hospital facilities or centers where clinics may be held. These clinics are held in cooperation with the local physicians and with specialists from the State Department of Health or from the state medical schools.

Industrial Hygiene

The wide use of chemistry in industry, the substitution of steam for water-power, the evolution of refrigeration, the increasing application of very high temperatures in working metals, the necessity of working in rarified and compressed air, the almost universal use of electrical energy in the mechanical arts, the development of rapid transportation, the extensive employment of artificial light, the strenuousness of a machine-set pace, and the overcrowding in manufacturing centers and in factories have produced new types of illness, have intensified the ravages of communicable disease, and have created industrial hygiene as an important branch of public health work.

Far-seeing managers of modern industries have found it to be as important to conserve, stabilize and render efficient their working forces as to prevent waste, adopt better methods of manufacturing, or to improve their salesmanship. They have noticed that output increases, their labor troubles diminish, and their overhead expenses decrease where human and mechanical engineering are best coordinated. They know that the most capable workman is healthy, contented, and is able to do his work rapidly and well.

The number of industries that are establishing welfare departments to deal with their employees is steadily increasing. Greater efforts are being made to improve the morale among workers by providing better sanitary conditions in work-shops, and by the construction of adequate safe-guards against accident, dust and fumes. Men and women are given medical attention and surgical care where the employer is responsible. Precaution is taken to prevent and to control communicable disease.

Sanitary lunch-rooms are provided to furnish adequate food at cost.. The employees are given instruction in safety-first, first aid,

and hygiene. When the labor is monotonous and exhausting, arrangement is made for rotation in work, period for relaxation permitted, and time allowed for recuperation.

The director of industrial welfare gives advice to the employees in the adjustment of social and financial difficulties. He endeavors to provide profitable recreation, and he encourages thrift, domesticity, and morality. There is a close relation between the home and the community life of a man and his industrial efficiency and reliability. While the worries which beset a workman are his private affair, they take a great deal of his attention from his job at the expense of his employer, and sooner or later become a problem for his physician. Tactful advice leading to contentment and constructive living is neither meddlesomeness nor paternalism,—it pays dividends to both employer and employee.

Medical Inspection of Schools

Preventive medicine does some of its best work in connection with public schools. Proper medical supervision of schools includes a school nurse service as well as medical inspectors. It applies to buildings and to equipment, as well as to the mind and to the body of the child. About twenty million children, nearly one fifth of the population of the country, are compelled to spend, on an average, five hours a day in school one hundred and sixty-five days in the year. Under such circumstances, as effective precautions should be taken to insure ventilation, lighting, heating, proper furniture and general sanitary conditions in the school to provide for the child's physical welfare as to enforce its attendance. It is obviously unfair to require a child to occupy a seat likely to produce body deformity or to study in a light that may impair its vision. It is equally unjust to bring together a number of young persons at an age when most susceptible to communicable diseases without medical supervision, unless the school is to provide a great disease exchange for the community. It must be remembered that the twenty million children of elementary-school age come in contact more or less intimately, with approximately twelve million others of pre-school age. These younger children are very susceptible to infectious diseases and are in the age group in which eighty-five per cent. of the mortality occurs.

When medical inspection is properly done, a disease history of the child is obtained on entry, and a number of defects and functional diseases will be discovered on examination that may be corrected. It provides a careful medical record preliminary to physical training, will determine in what individuals corrective gymnastics are needed, and, by periodical examination, will ascertain the physical progress of the child. The community should realize,

however, that it is of little value to spend money to discover defects unless provision is made to remedy them when they are found. Each school district should provide a dispensary service for school children and parents must be educated to consult their family doctor on questions of prevention before their children become ill.

Physical Education

Physical education is preventive medicine in action. It should have for its purpose the development of the functional power of the child to the highest level consistent with the most successful training of its intellect; it should meet the needs of the weak, who require it most, as well as of the strong; it should be graded for various ages; its progress should be determined by tests and measures of development, strength, agility, endurance and ability to do. Its proficiency should be based upon well-defined accomplishments, not upon certain periods of exercise.

In general, provision must be made for the physical education of three classes of individuals: (1) the physically normal, (2) the subnormal, (3) the abnormal and physically defective.

The physically normal individual should be required to take general exercise, but should be encouraged to select some form of sport and to acquire a fondness for it. In the primary school it may mean games and outdoor exercise; in the high school or college the development of an "athletic hobby" to keep him in "fighting trim" when required to lead a sedentary life.

The subnormal individual, underweight and understrength, for his age, undeveloped but organically sound, will require special and general exercise to meet the tests of normal. Having shown his ability by passing the required efficiency tests, he may be further educated in that group.

The abnormal group is composed of individuals distorted as to posture or carriage, but who may become greatly improved by corrective gymnastics. In this class are also those with heart lesions, hernia, diseases of the joints, marked flat feet, etc. A considerable number of these could be cured by proper surgery, and would be, if their parents were so advised by a medical inspector in whom they had confidence. All would be greatly benefited by special calisthenics and other light forms of exercise under medical supervision. In many instances members of this group have been led to attach too much importance to their condition. Nothing will do more than safe, beneficial exercise to lift them from the despair of chronic invalidism to the enthusiasm of physical well-being.

Physical education is a great antidote for antisocial tendencies. It teaches temperance, self-control, courage and endurance. It produces the ability to play the game to the end and to lose with a

smile or to take victory with modesty and magnanimity. It Americanizes and de-hyphenizes by the democracy of the playground and by the catholicity of its games. It places the nation on the solid foundation of physical soundness, morality, and vitality.

Organizations Promoting Public Health

Organizations promoting intelligent child labor legislation and passage of wise laws improving working conditions, particularly of women, are engaged in important public health work. Military training, the Boy Scout and Camp Fire Girl movements and mass athletics lead to physical vigor and constructive thinking. The practical application of mental tests and careful study of factors influencing their results stimulate interest in the social and physical welfare of children in the largest sense. The creation of parks and playgrounds provides fresh air, exercise, and shade essential for the well-being of children, especially of small children. City zoning tends to ventilate dwellings, to introduce sunlight into the home, to reduce noise and to purify the air. It leads to that restfulness essential to complete recuperation from a day's work.

The Demonstrative Method

Nothing equals in effectiveness a clear-cut demonstration of what can be done. The International Health Board is actively engaged in showing what results may be obtained by intensive practical application of preventive medicine. For example, it enters a community where malaria is prevalent, and concentrates its attack upon the disease by destruction of the breeding places of the mosquito, treatment of persons with malaria, and by screening all houses. It drains swamps, ditches, meadows, fills in or oils stagnant pools, clears away underbrush, and stocks the creek with top minnows to eat the mosquito larvae.

Its agents in cooperation with the local health organizations, visit every home in the community in search for defective drain pipes, uncovered rain barrels, and for bottles, cans, or other objects that may hold water in which mosquitoes may breed. The screening of the house is examined and advice is given as to how to make it most effective. If members of the family have malaria or give a history suspicious of the disease, they are examined clinically, and a course of quinine administered.

Such an intensive attack is invariably followed by a most significant reduction in the occurrence of malaria. As every home is visited, the work receives wide publicity. It becomes the chief topic of conversation at the meeting of the sewing circle, on the golf links, and at the corner grocery. On conclusion of his work, the director summarizes his findings, estimates the cost, and shows that the pre-

vention of malaria saves both money and suffering. He calls attention to the increased value of the drained land and the general improvement in appearance of the community by the removal of the underbrush and the stagnant pools. The people at first are skeptical, later become curious, and in the end are convinced that public health work of this type is of immediate value to them. They know what has been done and how it was accomplished, and are usually ready to see that the proper measures are adopted to prevent the return of the disease.

The intensive method has been widely used by the Rockefeller Foundation in its campaign against malaria and hookworm. In Framingham, Massachusetts, it is being utilized in the study and prevention of tuberculosis. The United States Public Health Service uses it in certain counties and towns for educational purposes and it has been employed by other organizations in the promotion of child welfare.

Disease Extermination

In certain strata of the earth are to be found the remains of animals and plants which once inhabited it, but were unable to survive the conditions of their environment. They perished for lack of food, could not adapt themselves to the variations of the soil, could not withstand the unfavorable alterations of temperature and moisture, or were unable to resist their enemies, both animal and vegetable. It is within the power of man to so alter his living conditions and to so change the environment of micro-organisms as to enforce either their biological modification or extinction.

The virus of smallpox would have a hazardous existence in a vaccinated world. The Schick test, toxin-antitoxin immunization and antitoxin administration present to the virulent diphtheria bacillus the problem of the American bison. Asiatic cholera and typhoid fever await the coup-de-grace of sanitation and inoculation. Successful warfare on the cootie brings extinction to typhus fever. Malaria and yellow fever are ready for the fate of the dinosaur, when means available are universally used in their eradication. Bubonic plague, the giant of pestilences, takes its place with the mastodon, when measures adopted to control it in America are used throughout the world.

Economics, sociology, and preventive medicine point to a hundred ways for the promotion of the public welfare,—to a thousand paths for the successful pursuit of health and happiness. It is futile to seek a far distant Utopia through a maze of "isms" and "pathies," when education to appreciate and to use the fruits of the research laboratories of the world will produce those living conditions and that healing which are the very essence of practical Christianity.

ELECTRONS AND ETHER WAVES[1]

By Sir WILLIAM BRAGG, F.R.S.

I PROPOSE to ask you this evening to consider for a short time one of the outstanding problems in physics. I am justified, I think, in saying that so far it has proved insoluble, but for all that, it lacks neither interest nor importance. It is important because it relates to very fundamental things with which we are deeply concerned, and as to its interest, it comes in many ways.

Man's interest in radiation is naturally very old indeed. The warmth of the sun, the light that it gives by day, and the light of the moon and stars by night, fill a first place in their importance to him. When experimental science began to grow rapidly its first efforts were devoted to an attempt to unravel the laws of propagation of light and heat. Among the famous pioneers Newton and Huyghens represented two opposing schools of thought. The former advocated a corpuscular theory of light, the latter maintained that light consisted of a wave motion. In a restricted sense, the wave theory has completely triumphed; it explains the ordinary phenomena of light and especially of the intricate effects which depend on interference of waves with the greatest satisfaction and precision. But, on a wider view of light phenomena, the victory of the wave theory is not so absolute, for it is certain that a great part is played by corpuscular radiations, the corpuscles being the electrons of recent discovery. It seems that we must admit the importance of each view and, to a certain extent, we can accurately define the part that each must play: but, there is one great exception. There is one problem in connection with the interrelations of electron waves and corpuscles which seems to ridicule all our attempts to understand it. If we could solve it we should have made an immense advance, both in knowledge and in our power of handling materials. We should perhaps have added a new province to the realms of physical thought. And it is because of this obvious importance and because of our failures to find the solution that I hope you will be interested in looking at the question once again in the light of recently acquired knowledge.

We are going to consider the relations between the energies

[1] The Robert Boyle Lecture at Oxford University for the year 1921.

carried by ether waves and the energy carried by electrons. Let us first set down the distinctive features of each form of radiation. As regards wave radiation, we must say that the energy spreads outwards and weakens as it spreads, just as a sound dies away in the open air. And next we must add that all waves show the extraordinary phenomenon of interference. Two sets of waves can tend to destroy each other's actions at certain places and times, making good such losses by increased actions at other places and other times. By the aid of this principle, Young and Fresnel, and a host of workers who have followed them, have built up optical theories of great power and completeness. Note that the characteristics of a simple wave are its length and its amplitude: it has no others.

Corpuscular radiations have been obvious to us on the grand scale only since the discovery of radium and of X-rays. Beside the X-rays, the projection of helium atoms from the bursting atoms of radio-active substances, we find in the general radiation of radio-active substances streams of high speed electrons. The main features of these rays which concern us now can also be stated briefly:

Electrons are to be found everywhere forming part of every atom. They can be set in motion by electric forces, as in the X-ray tube, or they may be expelled from radio-active substances. Such radiation like light radiation has qualities. The flying particles may be more or less in number, and the speed of each can fall between wide limits. In other respects it is, at present, assumed that they are all like each other. We have not been acquainted with electron movements so long as we have been acquainted with wave motions in ether. The reason is perhaps a simple one:

An electron can only maintain a separate existence if it is traveling at an immense rate from one three-hundredth of the velocity of light upwards, that is to say, at least 600 miles a second or thereabouts. Otherwise the electron sticks to the first atom it meets. The action of a powerful induction coil and space to move in freely, where there are no atoms to impede it, provide favorable circumstances for observation, and we have only been able to realize these conditions with sufficient success in more recent years.

We now know, therefore, radiation in two forms, and each is independently full of interest. But it is the extraordinary connection between them that is so fascinating and yet beats us when we try to explain it. We have known for many years that there is some connection between waves and electrons because light, especially of short wave length, can cause a discharge of negative elec-

tricity, that is to say, of electrons, from substances on which it falls. This, which is known as the photo-electric effect, has been carefully examined with a view to discovering relations between the wave length of the ether radiations and the velocity of the ejected electrons. But the experimental difficulties of obtaining a close insight into the effect were always considerable until we had to do with the new variety of light which Röntgen discovered. The very short wave length which is associated with X-rays goes with a photo-electric effect which is so greatly intensified that we can examine it in detail, and now the relation between wave and electron takes on an importance which arrests attention.

We can take the question in two stages: in the first as a general question. In the second we bring in effects which depend on details of atomic structure.

The general question can be stated quite simply. We have seen that a wave motion is defined by two qualities. The one, the wave length; the other the amplitude. When an X-ray falls upon any material substance we find that electrons are ejected: the wave radiation has produced an electron radiation. Electron radiation has characteristics also, namely, number and speed. In what way then are the characteristics of the waves related to the characteristics of the electron movements which are excited by them? The answer is simple but surely unexpected. The velocity of the electron depends on the wave length only; the number of electrons depends on the intensity, but not on the wave length. Moreover, the relation between the wave length of the one radiation and the velocity of the other is of the simplest kind. If we define the wave length by stating the number of waves that pass by a given point in a second and call this number the frequency, then the energy of the electron is equal to the frequency multiplied by a constant quantity. This constant is not new to us, it had already turned up in connection with investigation of interchange of energy, where waves are concerned, and is well known as Planck's constant. That, however, need not concern us now.

The essential point is that a wave radiation falling on matter of any kind whatever and in any physical condition, liquid or solid or gaseous, hot or cold, causes the ejection of electrons. In actual experiment we cannot usually examine the speed of the electron at the instant of its production. We have generally to wait for the electrons to get outside the body in which they arise before we can handle them in our experiments. Those that have come through the deeps of the material have lost speed by collision with the atoms on their way out. Consequently, we have in response to the incidence of waves of a definite frequency, that is to say, of so-called monochromatic radiation, an output of elec-

trons of various speeds ranging downwards from a maximum which is given by the above-mentioned relation. There does not seem to be any doubt that the electrons all had originally quite the same definite speed, and that the differences in speed are acquired subsequently.

In this process we see energy of wave radiation replaced by energy of electron radiation. There is an exactly converse process. If we direct a stream of electrons against any material substance we can call into being ether waves. They arise at the point of impact and their quality is, in the general sense, determined by the velocity which we have given the electron stream.

Among the waves so originated there are some whose frequency is related to the energy of the individual electron in the electron stream by the same constant as before. There are others of lesser frequency, such as we might suppose to be originated by electrons that belonged to the original stream, but have lost energy by collisions with the atoms of matter. Here again, there is no doubt that the electrons produce waves for which the frequency is exactly determined by the use of Planck's constant as above.

In order to realize the full significance of these extraordinary results, let us picture the double process as it occurs whenever we use an X-ray bulb. By the imposition of great electrical forces we hurl electrons in a stream across the bulb. One of these electrons, let us say, starts a wave where it falls. This action is quite unaffected by the presence of similar actions in the neighborhood, so that we can fix our minds upon this one electron, and the wave which it alone causes to arise. The wave spreads away, it passes through the walls of the bulb, through the air outside, and somewhere or other in its path in one of the many atoms it passes over an electron springs into existence, having the same speed as the original electron in the X-ray bulb. The equality of the two speeds is not necessary to the significance of this extraordinary effect; it would have been just as wonderful if one speed had only been one half or one quarter or any reasonable fraction of the other. The equality is more an indication to us of how to look for an explanation than an additional difficulty to be overcome.

Let me take an analogy. I drop a log of wood into the sea from a height, let us say, of 100 feet. A wave radiates away from where it falls. Here is the corpuscular radiation producing a wave. The wave spreads, its energy is more and more widely distributed, the ripples get less and less in height. At a short distance, a few hundred yards perhaps, the effect will apparently have disappeared. If the water were perfectly free from viscosity and there were no other causes to fritter away the energy of the waves, they would travel, let us say, 1,000 miles. By which time

the height of the ripples would be, as we can readily imagine, extremely small. Then, at some one point on its circumference, the ripple encounters a wooden ship. It may have encountered thousands of ships before that and nothing has happened, but in this one particular case the unexpected happens. One of the ship's timbers suddenly flies up in the air to exactly 100 feet, that is to say, if it got clear away from the ship without having to crash through parts of the rigging or something else of the structure. The problem is, where did the energy come from that shot this plank into the air, and why was its velocity so exactly related to that of the plank which was dropped into the water 1,000 miles away? It is this problem that leaves us guessing.

Shall we suppose that there was an explosive charge in the ship ready to go off, and that the ripple pulled the trigger. If we take this line of explanation we have to arrange in some way that there are explosive charges of all varieties of strength, each one ready to go off when the right ripple comes along. The right ripple, it is to be remembered, is the one whose frequency multiplied by the constant factor is equal to the energy set free by the explosion. The ship carries about all these charges at all times, or at least there are a large number of ships each of which carries some of the charges, and externally the ships are exactly alike. Also we have to explain why, if we may drop our analogy and come back to the real thing, the ejected electron tends to start its career in the direction from which the wave came. This is a very marked effect when the waves are very short.

Dropping the analogy, how do the electrons acquire their energy and their direction of movement from waves whose energy and momentum have become infinitesimally small at the spot where they are affected, unless the atom has a mechanism of the most complicated kind? And if the intervention of the atom is so important, why is it that in these effects a consequence of the intervention does not depend upon each atom itself—whether, for example, it is oxygen or copper or lead?

We may try another line of explanation and suppose that the energy is actually transferred by the wave from the one electron to the other. If it is the atom which pulls the trigger and causes the transformation, then how does it happen that the whole of the energy collected by the wave at its origin can be delivered at one spot? Rayleigh has told us that an electron over which a wave is passing can collect the energy from an area round about it whose linear dimensions are of the order of the wave length. But any explanation of this kind is entirely inadequate. Whatever process goes on it is powerful enough on occasion to transfer the whole of the energy of the one electron to the other. Nor can

there be any question of storing up energy for a long period of time until sufficient is acquired for the explosion. For it is not difficult to show that when an X-ray bulb is started and its rays radiate out, the actual amount of energy which can be picked up by an atom a few feet away would not be sufficient for the ejected electron, though the tube were running for months; whereas we find the result to be instantaneous.

I think it is fair to say that in all optical questions concerned with the general distribution of energy from a radiating source the wave theory is clearly a full explanation. It is only when we come to consider the movements of the electrons which both cause waves and are caused by them that we find ourselves at a loss for an explanation. The effects are as if the energy were conveyed from place to place in entities, such as Newton's old corpuscular theory of light provides. This is the problem for which no satisfactory solution has been provided as yet: that at least is how it seems to me.

No known theory can be distorted so as to provide even an approximate explanation. There must be some fact of which we are entirely ignorant and whose discovery may revolutionize our views of the relations between waves and ether and matter. For the present we have to work on both theories. On Mondays, Wednesdays, and Fridays we use the wave theory; on Tuesdays, Thursdays, and Saturdays we think in streams of flying energy quanta or corpuscles. That is after all a very proper attitude to take. We cannot state the whole truth since we have only partial statements, each covering a portion of the field. When we want to work in any one portion of the field or other, we must take out the right map. Some day we shall piece all the maps together.

Meanwhile, even if we cannot explain the phenomena, we must accept their existence and take account of them in our investigations. We must recognize that wave radiation and electron radiation are in a sense mutually convertible. Whenever there is one there must be the other, provided only there is matter to do the transforming. We do not yet know more than a little of the part that this process of interchange plays, but we know that it is very prominent when the waves are very short, or, what is the same thing, the electrons moving swiftly. It is the movement of the electrons in the X-ray bulb that originates the X-rays themselves. They as waves pass easily through the wall in the tube and through materials outside: their energy finally disappears and is replaced by moving electrons. It is the latter alone that produce directly the effects which we ascribe to X-rays. We may suspect that similar effects to these take place when the waves are long, but the corresponding electron velocities are so small that it is difficult to mea-

sure them or observe their effects. Nevertheless, the carrying forward to these regions of experience gained elsewhere has led to extraordinary results, as for example, in the theories of Bohr regarding the relations between the structure of an atom and the radiation it emits.

I have spoken of the first stage in this examination of the relations between ether waves and electrons. May I now go one step further and bring in certain curious and lately discovered relations between the interchanges and the nature of the atom itself. All that I have said before is mainly independent of atomic nature; I want now to consider certain experimental results which are superimposed upon the former without in the least invalidating them and which obviously have a first importance on our appreciation of atomic structure.

When an X-ray of given wave length strikes an atom, it may result in the ejection of an electron of equivalent energy as described above. And in such a relation between wave length and energy there can be no trace of any influence of the nature of the atom. But it may sometimes happen that the energy instead of being handed over or transformed in one complete whole is transformed in a series of successive stages, and these stages are really characteristic of the atom. Let me give an illustration:

Let us imagine an X-ray of wave length equal to two-tenths of an Angström unit (100-millionth of a centimeter), such as comes, under ordinary circumstances, from a powerful X-ray bulb. It falls on a silver atom; it may, as in the general process, produce an electron of energy equivalent to itself, but it may also divide up this energy into two parts. One part is characteristic of the silver atom. It is an amount which the silver atom is for some reason especially liable to absorb or develop. It is peculiar to the silver atom, no other atom absorbs just that quantity. Leaving out of account for the moment the balance, let us follow the course of happenings to this particular quantity of energy. It excites in the atom a series of rays characteristic of the atom. These rays are divided into groups characteristic of the atom, but of a general arrangement which is the same for all atoms. It appears that the absorbed energy is divided up between various rays, probably giving rise to one out of each group, and in that way its whole total is spent.

These rays we now analyse with an X-ray spectrometer using a crystal as our diffraction grating. It is by their use that we have been able to study the architecture of crystals and to find the way in which the atoms, under the influence of their mutual force, arrange themselves in crystalline form.

Going back for a moment to the balance, the difference between the energy characteristic of the original X-ray and that amount of

energy which was used up in the way just described, this energy it appears is found in the possession of an electron whose velocity can be measured with accuracy. Here we have an extraordinary instance of a partition of energy between wave and electron. We find the action of a wave resulting in the initiation of both electrons and waves, but the simple relation which we had in the general case is only modified to a slight degree. There may be several items instead of one in our balance sheet, but the balance is still good. This action follows just as well as a consequence of the impact of an electron having the necessary energy as it does from the incidence of an X-ray in the way I have described. We should notice in addition that when X-rays or electrons fall short in their associated energy of the amount characteristic of the atoms, there is no result at all, and this is reflected in the fact that neither of them is absorbed in the atom so much as if they were respectively a little higher in frequency or a little greater in velocity.

The curious and essential feature of all this mass of information which I have been trying to put before you in a rough and summary form is the interchangeability of ether waves and electrons. Energy can be transferred from one to another through the agency of matter. The transference is governed by the simplest arithmetical rules. In the exchange it is the frequency of the wave which is to be set against the energy of the electron, and it is just this that makes the greatest puzzle in modern physics. It is the block at one point which is choking the entire traffic and on which, therefore, all our interests must concentrate.

CHEMISTRY OF THE BLOOD ONE HUNDRED YEARS AGO

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THE recent appearance of a paper[1] discussing the chemical changes which occur in the blood concomitant with various disease conditions calls to mind a series of studies of this fluid made one hundred years ago. In 1821, the leading Swiss scientist of the time, J. L. Prévost, and his student, J. B. A. Dumas, who became the foremost French chemist during the middle of the nineteenth century, published in the "Bibliothéque Universelle, Sciences et Arts," volumes seventeen and eighteen, a series of three papers entitled "Examen du Sang et Son Action dans les Divers Phénomènes de la Vie."[2] To the present-day mind these papers are interesting not merely because they are accounts of studies made one hundred years ago, but because they touch upon a variety of topics, each of which in the course of a century's progress has attained to a greater or lesser degree the rank of a separate science. It would serve no purpose to point out the several paths followed in this development; those who are at all familiar with the history of the natural sciences, particularly chemistry, realize that they must read the nineteenth century in its entirety if they would know the complete story of that development.

In their earliest communication Prévost and Dumas state that the relation of the blood to the nervous system is primarily the subject of their research. Inasmuch as the changes occurring in this master tissue were believed to be slight and difficult to detect, the blood was made the special object of study. The first paper of the series deals with certain purely physiological and morphological aspects of the study together with an account of some experiments concerning blood transfusion. In the second article are presented the results of chemical analyses, while the last communication deals essentially with the phenomenon of secretion.

The conception of the general character of the blood as a fluid containing many minute red globules suspended therein was an

[1] Myers, V. C.: *Journ. Lab. Clin. Med.*, V, 343 (1920).
[2] XVII, 215, 294. XVIII, 208.

inheritance from the early micrographers. Prévost and Dumas were unable to see how the fluid portion of the blood could influence the nervous system, and therefore easily persuaded themselves that a study of the *red globules* could furnish the desired information regarding the action of the blood during life. In the morphological studies which were made, the shape of the blood corpuscles was the first point to receive attention. Sir E. Home had set forth the view in his Croonian Lecture for 1818[3] that the red blood cells are spherical bodies "composed of a central globule and a coloring-matter envelope." During the latter part of the eighteenth century Hewson had published an account of observations of the blood and had considered the corpuscles as flat plates furnished with a "saillant" point in their center. By this "saillant" point was doubtless meant what we now understand as the nucleus, for, as Prévost and Dumas remark, Hewson was led to this view as a result of examining the blood of the toad and the frog, forms in which the erythrocytes are recognized by present-day histologists as being nucleated. In order to determine which of these two views was the correct one, Prévost and Dumas examined the blood of forty-five different species of animals. Descriptions were given for each sample and the corpuscles were measured. The measurements were made by means of a camera-lucida arrangement, the object being traced on the camera-lucida field and its real dimensions deduced by a knowledge of the magnification employed. It is interesting to compare the diameter of the human erythrocyte as determined by these investigators with that given in modern textbooks. Prévost and Dumas obtained 6.6 microns as their result while present-day textbooks state approximately 7.5 microns. The smallest value noted by these workers was 3.8 microns, this being the diameter of the erythrocyte in the goat *Capra Hircus*.

Some of the conclusions reached were as follows: the globules are circular in shape in all mammals, their size varying among different species; they are elliptic in birds with but slight variation in size in this class; in all cold-blooded animals the erythrocytes are elliptic in shape.

Blood transfusion as a therapeutic measure has had a long history. The success of the operation was never assured, however, until comparatively recent times; there were unknown factors operating, when blood from one individual was introduced into the vessels of another, which too often led to fatal results. This was particularly true a century ago and earlier, when the blood of animals was occasionally transfused into the human being. With

[3] *Philosophical Transactions, 1818,* 172 & 185.

the discovery by Prévost and Dumas that demonstrable morphological differences exist among the bloods of different animals, it was natural for them to assume that such differences accounted for the varying results obtained when blood was transfused. They performed a series of experiments to test this idea. It was shown: (1) that in general, transfusion of blood between animals of the same species is a complete success; (2) that between animals having "globules" of the same shape but of different dimensions transfusion after severe hemorrhage results in only a partial relief of short duration; while (3) injection of circular "globules" into a bird results in death following "violent nervous symptoms comparable to those obtained after the administration of the most intense poisons."

In their chemical examination of the blood Prévost and Dumas fixed their attention upon "l'albumine"[4] of the serum and the "coloring matter which surrounds the globule." As would be expected, no very exhaustive examination of these substances could be made considering the fact that suitable methods for analyzing organic compounds were not available. The name "l'albumine" was being applied to a complex something contained in the blood serum largely because it possessed the property of coagulating under the influence of heat in a manner similar to egg-white, and indeed, very little more was known concerning this substance. The coagulation temperature of "l'albumine" of the serum was determined to be 75° Centigrade.

Analyses of a general character were made upon the blood of twenty different species of animals; both the whole blood and the serum were analyzed for "eau, particules," and "albumine et sels solubles." In analyzing different samples of blood from the same animal it was noticed that the results did not always agree. It was reasoned that under certain conditions the veins must absorb considerable blood material; experiments were therefore performed to see how quickly the animal body could regenerate blood. Successive hemorrhages were made and the blood samples which were drawn at intervals were analyzed. The only change worthy of note was the content of corpuscles in the whole blood; the difference was slight, however, and Prévost and Dumas concluded that the veins are able to absorb blood material rapidly. In the light of modern physiology it would be said that these experimenters obtained a decrease in the erythrocyte content of the blood. An examination of the serum analyses submitted shows that remarkably constant

[4] This should doubtless be translated as "albumen," which is used by modern physiological chemists in a generic sense; it is quite clear, however, that Prévost and Dumas considered "l'albumine" to be a single substance.

values were obtained for the water and the albumen. The following conclusions are of interest: (1) arterial blood contains more "particules" than does venous blood; (2) the blood of birds contains relatively the largest number of "particules"; (3) the blood of mammals comes next and among them the carnivora seem to have more than the herbivora, while (4) the cold-blooded animals appear to possess relatively the smallest number.

Three experiments were performed in studying the coloring matter of the blood.

"(1) When ashed in an open crucible . . . . there resulted a considerable quantity of red powder more or less rich in peroxide of iron according to the nature of the blood employed; (2) when treated by boiling nitric acid so as to destroy the animal matter, a clear colorless fluid resulted in which a few drops of prussiate of ammonia formed a large amount of blue precipitate; (3) when dissolved by means of caustic potash and the resulting solution boiled with prussiate of ammonia, a brown liquor was obtained, in which the addition of a quantity of oxalic acid sufficient to saturate the potash brought about a precipitate of a greenish-blue color, which was nothing else than the albumen colored by the prussian blue."

All of these experiments confirmed the idea that the coloring matter of the blood "est formée d'une substance animale en combinaison avec le péroxide de fer." It was suggested that this animal matter might be "l'albumine" although the caution of these authors prevented them from being dogmatic on this point; they preferred to leave the question open for future research to decide.

When considering the phenomenon of secretion and the behavior of egg-white through which is passed a galvanic current, Prévost and Dumas approached the problem with the formula which was current at that time. The interesting topic of the day was electricity. Davy discovered the power of the electric current to decompose potash and soda in 1806; Oersted observed the effect of an electric current on a magnet in 1819; Ampère followed this in 1820 by showing that the direction in which a magnet moves depends upon the direction in which the electric current flows relative to the magnet. This dominating interest in electricity in 1821 is easily revealed by a perusal of the volumes in which the papers of Prévost and Dumas appeared; there are to be found papers by such men as Ampère, Arago, Oersted, Davy and Faraday.

Prévost and Dumas were not immune against this electric virus; they were interested in the experiments reported by an investigator who had tested the effect of a galvanic current on egg-white. The current had decomposed the egg- white, "the coagulated albumen wandered to the positive pole, and the caustic soda to the negative pole." This experiment was interpreted by the students of that early day to mean "that the white

of egg is to be regarded as an albuminate of soda with excess of base.'' Prévost and Dumas repeated this experiment and examined microscopically the coagulum which collected about the positive pole. They found globules similar to those found in milk, pus, blood and muscle. This observation led them to make a generalization concerning the phenomenon of secretion.

Nous considérons la surface circulante de chaque organe sécréteur comme douée d'une polarité constante en vertu de laquelle les produits de la sécrétion sont formés et isolés. Et si l'on se rappelle que les mucus et les produits non globuleux sont généralement alkalins; que, d'un autre coté le lait, le pus trés-sain, le chyme, et les muscles, sont globuleux et acides, on reconnoitra la plus grande analogie entre leur formation et celle des deux corps que nous obtenons dans l'experience galvanique sur l'albumine.

Just as evolution has been the formula of the past half century with which to explain all things, physical or metaphysical, animate or inanimate, and appears about to give way to a new formula, namely, relativity, so electricity was the formula one hundred years ago. There is in the passage cited above, in which polarity was brought into relation with secretion, simply an attempt at using the formula of the time. Another very interesting use of this formula is to be found in the closing chapter of Thomson's History of Chemistry published in 1830.[5]

From the mouth the food passes into the stomach, where it is changed to a kind of pap called *chyme*. The nature of the food can readily be distinguished after mastication; but, when converted into chyme, it loses its characteristic properties. This conversion is produced by the action of the eight pair of nerves, which are partly distributed on the stomach; for when they are cut, the process is stopped: but if a current of electricity, by means of a small voltaic battery, be made to pass through the stomach, the process goes on as usual. Hence the process is obviously connected with the action of electricity. A current of electricity, by means of the nerves, seems to pass through the food in the stomach, and to decompose the common salt which is always mixed with the food. The muriatic acid is set at liberty, and dissolves the food; for *chyme* appears to be simply a solution of the food in muriatic acid.

The first definite proof—as far as the writer has been able to determine—that urea exists in the blood was furnished by Prévost and Dumas exactly one hundred years ago. In the third paper of the series under consideration, these authors described certain experiments in which both kidneys were removed from animals (dogs, cats and rabbits). Analysis of the blood of such animals showed the presence of a large amount of urea which was separated by means of the nitrate method; the urea was identified by determining its properties and by performing an elementary

[5] Page 319.

analysis. From the blood of unoperated animals, on the other hand, no such substance could be isolated.

The significance of their discovery was fully appreciated and the authors discussed its bearing on the theory of renal secretion. The failure of other experimenters to show the presence of urea in the blood of normal animals had been interpreted to mean that the substance was not present in the blood but was formed in the kidney; the same idea of kidney function was held by Berzelius who maintained that the kidney was the organ for oxidizing sulphur and phosphorus (considered by him to be elements of albumin) since sulphates and phosphates were found in the kidney secretion in relatively large amounts but were absent from normal blood. Prévost and Dumas concluded that urea was eliminated by the kidney to a degree corresponding to its formation *elsewhere in the body:* ablation of both kidneys, as had been performed in their experiments, resulted in a failure of the body to eliminate this substance and consequently its accumulation in the blood in a quantity sufficient to enable its isolation and identification. This new point of view, namely, that the kidney functions to eliminate substances which are already present in the blood, they felt was supported by the evidence obtained from the study of gout. The existence of sodium "lithate" calculi in the joints was considered as evidence for the existence of sodium "lithate" in the blood. Since the secretion from the kidney contained sodium "lithate," it was considered possible that the calculi form in the joints because the blood contains too much for the kidneys to eliminate, and this idea for many decades has been the principle underlying the therapy of gout.

Prévost and Dumas thus enunciated a new view of kidney function. That view has come down to the present as the working principle which guides the physiological chemist in much of his work on the chemistry of the blood and of the kidney secretion. In the course of a hundred years, however, with the development of organic chemistry and the invention of methods there has appeared such a refinement of procedure that micro methods have in a great many cases taken the place of the more cumbersome—but not less accurate—macro or gravimetric methods. Instead of the modern physiological chemist being required to perform operations of a drastic sort such as the complete removal of both kidneys, or compelled to work with large quantities of material, or to perform combustions over a coal fire, he takes, as is indicated in one of the current methods,[6] such a small quantity as ten cubic centimeters

[6] Folin and Wu: *Journ. Biol. Chem.*, XXXVIII, 91 (1919).

of blood and analyzes it for non-protein nitrogen, urea, creatine, creatinine, uric acid, and sugar, some of which are present in as small quantities as a few milligrams per one hundred cubic centimeters of blood. To these might be added calcium, chlorides, phosphates, amino nitrogen, cholesterol and the acetone bodies and still the list would be incomplete.

Following the lead of Prévost and Dumas, and others who might be mentioned, the modern physiological chemist, armed with new weapons for research, is pushing his chemical studies back beyond the membranes of the kidney glomeruli and tubules to the blood, and discovering relations of inestimable value to medical science. The following words, written in 1821, are still worthy of attention in 1921:

> General hydropsy, hematuria and many other affections enter a new day when considered from this particular point of view. The characters of the kidney secretion acquire a very powerful interest in that they serve to indicate the condition of the mass of the blood and the typical changes to which this important fluid is subject.

For the scientist especially, the story of the past is the record of progress in methods through which problems are approached and in ideas which direct the activities of the investigator. He who inherits by virtue of his scientific lineage all of the achievements of by-gone days would do well not to exalt unduly his own efforts or fail to appreciate his debt to those who laid the foundations upon which the more modern structure is built. The substance that seems relatively simple to the modern chemist has not always appeared in this light; it has often been necessary to unravel a mass of seemingly conflicting data in order to reveal this simplicity. The chemistry of the blood in 1821 consisted essentially of a small body of facts concerning the blood-clot, the coagulable proteins, the coloring-matter, and a few soluble salts; the passing of a century has resulted in the advancement of this particular branch of knowledge almost to the rank of a separate science. The only standard by which the work of the present may be compared with that performed one hundred years ago is that of the scientific method itself; that our fore-fathers in 1821 used this method well is certified by the fact that their results have stood the test of time; whether or not the contribution of 1921 shall possess the same clear title to longevity depends upon the degree of keen insight into problems, the skill in the use of methods, and finally the measure of self criticism which may be existent among the present generation of investigators.

ENUMERATION ERRORS IN NEGRO POPULATION

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THE Bureau of the Census was established for the purpose of enumerating the population of the United States, and for the collection and collation of other statistical data bearing on the social welfare of the nation. The government bases its calculations upon the information furnished by this bureau. The basis for congressional representation, military conscription and other federal regulations are based upon the census enumeration within the limits of the several states. Publicists and social philosophers base their conclusions upon the same data. It is, therefore, a matter of the greatest importance that the enumeration should be reliable and trustworthy. The Bureau of the Census ranks as a scientific department of the government. Constantly repeated errors of this bureau tend to impeach its scientific reputation and to vitiate the conclusions based upon its output. Numerous complaints have been made by competent critics not only repudiating the results, but also impugning the motive. Manipulation in behalf of sectional and partisan advantage has been freely charged. Senator Roger Q. Mills, in an article in *The Forum,* bitterly complained that the south was deprived of its due quota of representation by the imperfection of the enumeration of 1890. Indeed, the alleged inaccuracies of the eleventh census provoked a flood of condemnatory literature.

Various enumerations of the negro population by the Census Office since 1860 have not been very flattering to the scientific reputation of that bureau. These enumerations have been not only inherently erroneous, but so conflicting and inconsistent as to demand calculated corrections. It may be taken for granted that the enumerations up to 1860 were reasonably accurate and reliable. The negroes, up to that time, were in a state of slavery, and the master had merely to hand the list of his slaves to the enumerator, just as he would the list of his cattle or other forms of chattel. There was every facility and every reason for accurate returns. The negro population up to 1860 was inflated by importation of slaves from Africa, and, consequently, it was impos-

sible to check the accuracy of the count by the ordinary statistical tests. Beginning, however, with the census of 1870, this population has been cut off from outside reinforcement and has had to depend upon its inherent productivity for growth and expansion. It, therefore, becomes an easy matter to apply the ordinary statistical checks to test the accuracy of enumeration.

It is conceded that the enumerations of 1860, 1880, 1900 and 1910 were accurate within the allowable limit of error. According to these enumerations, the growth was more or less normal and regular, and conformed to the requirements of statistical expectation. But the enumerations of 1870, 1890 and 1920 are so flagrantly discrepant as to demand special explanation and correction. A miscount at one enumeration upsets the balance for two decades. If it be an undercount, it makes the increase too small for the preceding decade and too large for the succeeding one. Accordingly, the only consecutive decades upon which we can rely for accuracy concerning the growth of the negro population would be the 1850-1860 and 1900-1910. In order to escape obvious absurdities, the figures for the other decades must be supplied by reasoned interpolations. The mere exhibit of the several enumerations by the Census Office will convince the student of their inherent improbability.

NEGRO POPULATION AT EACH CENSUS, AND DECENNIAL INCREASE, 1860-1920

Year.	Number.	Decennial Increase.	Per cent. of Increase
1860	4,441,830	803,022	22.1
1870	4,880,009	438,179	9.9
1880	6,580,793	1,700,784	34.9
1890	7,488,676	907,883	13.8
1900	8,833,994	1,345,318	18.0
1910	9,827,763	993,769	11.2
1920	10,463,013	635,250	6.5

The irregularities of these figures are as whimsical as if produced by the sport of the gods. The normal growth of population uninfluenced by immigration or emigration shows a gradual increase in decennial increment and a gradual decline in the rate of increase. Wherever there is found to be a wide divergence from this law, it must be accounted for by special contributory influences. The column giving the decennial increments, instead of showing a gradual behavior, jumps back and forth with unaccountable capriciousness. A sudden drop from 803,022 to 438,179 is offset by an alarming rise to 1,700,784 for the next decade, when, lo and behold, there is a swift decline to 907,883 for the following ten years. We look aghast at the upward bound to 1,345,318, thence a downward drop to 993,769, followed by a still further

startling decline to 635,250. It makes the head swim to try to keep track of such whimsical variations. The decadal increase per cent. shows similar irregularities. The rhythmical rise and fall of these figures impresses one as the alternate up and down motion of boys playing at see-saw. Why should the ordinates of a curve, which should move smoothly downward, drop suddenly from 22.3 to 9.9, then rise to 34.9 and drop again to 13.9, then rise to 18.0 and decline again to 11.2 with a final slump of 6.5? Such variability has perhaps never been experienced by any human population. The internal evidence of error is overwhelming. The Census Bureau has sought to make corrections for the evidently erroneous enumerations of 1870 and 1890. But the equally discrepant figures of 1920 remain so far indisputed.

The census of 1870 has been universally discredited. The greatest error of enumeration falls, naturally enough, on the negro race. This race had just been set free, and had not reestablished itself in definite domiciles. Political conditions in the South were in the flux and flow of readjustment. The machinery of the Census Bureau was not sufficiently efficient to cope with so complicated a situation. Statisticians, recognizing the evident error, have tried to correct the mistake by statistical computation. The Census Bureau estimates the error in the negro population for the decade to be 512,163. An acknowledged error of a half million, it would seem, would put this bureau on the lookout for similar errors in the future. But the census of 1890 was notoriously faulty. Here again the undercount, it is obvious, fell mainly in the South, and largely among the negro population.

The Census Bureau, in commenting upon the apparent irregularities of returns for 1890, states: "According to the returns, the rate from 1880 to 1890 was very much lower than even the last rate, that of 1870-1880, and the rate for 1890-1900 was much higher than during the preceding or succeeding decade. Such abrupt changes in a class of the population which is not affected by immigration seem very improbable and almost force the conclusion that the enumeration of the negroes in 1890 was deficient. In the special volume on "Negro Population of the United States 1790-1915," the director further declares:

> The presumption of an undercount at the census of 1890, therefore, rests upon the improbability of the decennial rates of increase themselves as developed from the census returns; the inconsistency of the indicated changes in the rates from decade to decade with the changes in the proportion of children in the negro population, and upon the improbability of the decennial mortality indicated for the decades 1880-1890 and 1890-1900. . . . . The number of omissions at the census of 1890 cannot be accurately determined, but it would seem to be a fair assumption that the decline in the rate of increase from

decade to decade was constant, and that the rate fell off in each of the two decades 1880-1890, 1890-1900 by approximately the same amount. On this assumption, the probable rates of increase for the four decades, 1870-1910, are 22.0, 17.9, 13.8, 11.2. . . . A rate of 17.9 per cent. for the decade 1880-1890 would give a negro population in 1890 of nearly 7,760,000, which, in round numbers, exceeds the population as enumerated at the census of 1890 by 270,000. This is probably the number of omissions of negroes at the census of 1890, on the assumption that the retardation in the rate of growth in the 20 years 1880-1900 was constant.

By making the estimated corrections for acknowledged error in the counts of 1870 and 1890, decadal growth from 1880 to 1890 would be reduced and from 1890 to 1900 increased, so as to produce reasonable conformity with the laws of normal growth. A gradual decline in the rate of growth from 22.3 per cent. to 11.2 per cent. in 60 years will prove that the negro element conforms to the regular law of human population. This decline would appear even more gradual if we consider that the rate of 22.1 from 1850 to 1860 was contributed, in considerable measure, by African importation. The Census Bureau offers the following table with corrected numbers for 1870 and 1890:

NEGRO POPULATION: DECENNIAL INCREASES, WITH ESTIMATED ALLOWANCES FOR 1870 AND 1890

Year.	Number.	Decennial Increase.	Per cent. of Increase.
1910	9,827,763	993,769	11.2
1900	8,833,994	1,073,994	13.8
1890	7,760,000	1,179,207	17.6
1880	6,580,793	1,188,621	22.0
1870	5,392,172	950,342	21.4
1860	4,441,830	803,022	22.1

According to the recent bulletin issued by the Bureau of the Census, the negro population showed a surprising and unexpected decline during the last decade. In 1910 there were 9,827,763 negroes, and in 1920 10,463,013, giving a decadal increase of 635,250 or 6.5 per cent. If these figures were added to the table corrected to 1910, the disparity would be as glaring as any which has yet come from the Census Bureau. The sudden drop in decadal increase from 993,769 to 635,250, or from 11.2 per cent. to 6.5 per cent., is so strikingly out of harmony with the more or less regular movement of the table as to call loudly for correction or explanation. The table shows a gradual decrease in the decennial increment from 1880 to 1910, a decline of 194,852 in three decades. But now we are called upon to accept a sudden decline of 358,519 in a single decade.

The decennial rate of increase dropped from 11.2 per cent. between 1900 and 1910 to 6.5 per cent. between 1910 and 1920,

whereas we should have expected a gradual decline of not more than 1 or 2 points. On the face of the figures it seems probable that the Census Bureau has again committed an error in the enumeration of the negro population. As this bureau has admittedly committed grave errors in enumeration of the negro population in two preceding censuses, it is but reasonable that the obvious discrepancy can be most reasonably accounted for by an error in the present count.

Aside from the internal evidence itself, there is sufficient reason to suppose that this count might have been erroneous. The mobile negro population has been greatly upset by the world war. There was a mad rush of negroes from the South to fill the vacuum in the labor market caused by unsettled conditions. Thousands of negro homes were broken up and their members scattered without definite residential identity. In the cities especially, it seems probable that the count was greatly underestimated. The negro migrants lived for the most part in improvised lodgings and boarding houses whose proprietors had little knowledge and less interest in the identity of the boarders. The census official, visiting such boarding houses with a large number of negro boarders would, in all probability, receive an inaccurate underestimate by the ignorant and uncaring proprietors. As an illustration of such inaccuracy, I cite a quotation from an editorial of the *Dispatch* of Oklahoma City:

> If the census enumerators over the United States were as careless in the count as they were shown to be by this publication during the poll of the population last year, the general charge is right that the black man has made a much larger numerical advance than the official, yet faulty, records show. It will be remembered that the *Dispatch* made the charge during the enumeration that there was a laxness and really seeming desire to overlook the black man in this city. Our charge was printed in the daily papers. To cap it all off, the irate enumerator in the section of the city where the *Dispatch* is located, appeared on the evening that the charge was published, and demanded of the editor the basis of the charge. We took him out into the 300 block on East 2nd Street and found 33 black men whom he had not counted, folk who told him so, and whose names he did not have on his lists.

If a presumption of undercount was justified by the statistical indication for 1870 and 1890, surely a like presumption would obtain for the census of 1920. There are but three methods of accounting for this sudden slump in the growth of the negro population. First, an undercount of the Census Bureau, second, a sudden increase in the death rate, and third, a decrease in the birth rate of the negro population.

It is known that the death rate of the negro is decreasing rather than increasing under improving sanitary conditions and general

social environment. The Director of the Census states that "the death rate has not changed greatly." Instead of adhering to the "fair assumption" of a steadily declining rate of increase, as was done for the faulty enumerations of 1870 and 1890, the Director of the Fourteenth Census accepts the violent leap from 11.2 to 6.5 and endeavors to vindicate the count of 1920, by assuming a sudden decrease in negro birth rate.

On this point the Census Bureau explains:

> The rate of increase in the negro population, which is not perceptibly increased by immigration or emigration, is by far the lowest on record. This element of the population has been growing at a rapidly diminishing rate during the past 30 years, its percentage of increase having declined from 18 per cent. between 1890 and 1900 to 11.2 per cent. during the following decade and to 6.5 per cent. during the 10 years ended January 1, 1920. Such data as are available as to birth and death rates among the negroes indicate that the birth rate has decreased considerably since 1900, while the death rate has not changed greatly.

The statement, "this element of the population has been growing at a rapidly diminishing rate during the past 30 years," that is, since 1890, presupposes the accuracy of the census of 1870, which presumption the census office itself discredits in a previous statement. It entirely overlooks the fact that the rate rose suddenly from 13.8 for 1880-1890 to 18.0 for 1890-1900. With the indicated corrections the rate of increase has declined within the expected limits of fluctuation from 22 per cent. for the decade 1850-1860 to 11.2 per cent. for the decade 1900-1910, making a drop of 10.8 points in 6 decades. The sudden downward drop by 4.6 points in a single decade certainly calls for a more satisfactory explanation than a sudden and unaccounted for decrease in birth rate. The only statement which the Census Bureau vouchsafes to account for this rather startling conclusion is a very hesitant and uncertain one:

> Such data as are available with regard to birth and death rate among negroes indicates that the birth rate has decreased considerably since 1910, but the death rate has not changed greatly.

On examining the data on which this conclusion is based, we find that they are wholly insufficient to justify the sweeping conclusion imposed upon it. The mortality statistics are based upon returns from the registration area. Only five southern states are now included in the area, namely, Maryland, Virginia, North Carolina, South Carolina and Kentucky, from which birth and death rates are collected annually, and even these states were not admitted to the birth registration area in 1900. So that the computation of birth and death rates for the colored population of these states is neither adequate nor convincing.

BIRTH RATE OF NEGRO POPULATION IN SPECIFIED REGISTRATION STATES, 1900 AND 1919 (COMPARATIVE)

STATES AND COLOR	BIRTH RATE 1900	BIRTH RATE 1919
Maryland:		
White	25.7	19.0
Colored	27.9	26.7
Virginia:		
White	31.5	25.9
Colored	33.1	27.8
North Carolina:		
White	34.3	29.3
Colored	36.5	28.5
South Carolina:		
White	32.3	27.1
Colored	38.2	26.2
Kentucky:		
White	31.2	24.7
Colored	25.2	17.7

Those are the only heavy negro states within the registration area.

These states were not all included in the registration area for 1900. Mortality statistics in the non-registration area are notoriously inaccurate and unreliable. Birth registration is especially unsatisfactory even in the registration area.

Return of negro births would naturally be most inaccurate. Negro births, especially in rural and small urban communities are not always attended by regular physicians or certified health officials. The midwife still plies her trade. There is a relatively large number of illegitimate births among negroes. Official returns in such cases would not be apt to be rendered fully for prudential reasons. It is therefore evident that the rapidly declining birth rate revealed by the census is based upon noncomparable and inadequate data.

Even the apparent rapid increase in the white death rate awaits fuller explanation before the figures can be relied upon with assurance. It is curious to note that the birth rate among the whites in South Carolina fell from 32.3 in 1900 to 27.1 in 1919, the death rate rising but slightly from 10.4 to 10.6 during the same interval. And yet the white population of that state increased from 557,807 in 1900 to 818,538 in 1920. There was a vigesimal increment of 250,731 with little or no reinforcement from immigration. This unexplained increment in the white population seems also to discredit the reliability of the recorded mortality statistics within the states so recently added to the registration area.

It is well understood that these states, except South Carolina,

have shown a comparatively slow rate of increase in negro population for 30 years preceding the census in question. The facts are indicated in the following table:

DECENNIAL RATE OF INCREASE OF THE NEGRO POPULATION IN CERTAIN REGISTRATION STATES: 1880 TO 1910

	RATE OF INCREASE		
NAME	1890	1900	1910
*United States	13.5	18.0	11.2
Maryland	2.6	9.0	—1.2
Virginia	.6	4.0	1.6
North Carolina	5.6	11.3	11.7
South Carolina	14.0	13.6	6.8
Kentucky	—1.2	6.2	—8.1

From the table it will be seen that the increase in negro population in the southern states within the registration area has been considerably lower than that for the country at large. In Maryland, there is an actual decline in the negro population of 1.2 per cent, from 1900-1910 and the small gain of 2.6 from 1880-1890. In Virginia the highest rate of increase during the past 30 years was 4 per cent. In Kentucky there was an actual decline for two of the three decades. The low rate of increase in the border states is due to the large emigration of the negro from these states to the nearby northern states and cities. It is well known that the negro who migrates to the North and the large cities is made up of younger people of both sexes who, if they had remained at home, would naturally tend to increase the birth rate.

The low birth rate revealed by the census in these states is due to the migration of the negro population of reproductive age from those states within the registration area. This, of course, does not affect necessarily the birth rate of negro population as a whole. A better view of the birth rate of the negro population may be secured by considering the growth of this population in the more typical southern states not so much affected by migration during the same period.

DECENNIAL RATE OF INCREASE OF THE NEGRO POPULATION IN CERTAIN NON-REGISTRATION STATES: 1880-1910

NAME	1890	1900	1910
United States	13.5	18.0	11.2
Georgia	18.4	20.5	13.7
Alabama	13.1	21.9	9.8
Mississippi	14.2	22.2	11.2
Louisiana	15.6	16.4	9.7

Thus it will be seen that four heavy negro states, with an aggregate negro population of nearly four million, shows a rate of increase far greater than those in the registration area. The in-

*Footnote: Exclusive of population especially enumerated in 1890.

crease in those states was due wholly to the excess of births over deaths. But this does not tell the whole story. While the stream of migration was not so pronounced from these states as from the northern tier of southern states, still there has been a considerable northern movement for the past three or four decades.

From a comprehensive view of the whole situation, it seems perfectly clear that the sudden decline of the negro population as revealed by the census of 1920 is due to miscount rather than to the declining birth rate. If we should estimate an error in count of 300,000, scarcely greater than that conceded by the Census Bureau itself for the count of 1890, the negro population during the past 60 years would have followed more or less consistently the ordinary laws of growth. Let us accept the substantial accuracy of the census of 1860, 1880, 1900 and 1910 and estimate the error for 1870 at 512,163, for 1890 at 270,000, as conceded by the Census Bureau, and let us still further allow an error in the count, 300,000 for 1920, as here suggested. The growth of the negro population since 1850 will be as follows:

NEGRO POPULATION

	Number.	Decennial Increase.	Per cent. of Increase.
1920	10,763,013	935,250	9.6
1910	9,827,763	993,769	11.2
1900	8,833,994	1,073,994	13.8
1890	7,760,000	1,179,207	17.6
1880	6,580,793	1,188,621	22.0
1870	5,392,172	950,342	21.4
1860	4,441,830	803,022	22.1

The table makes the negro population behave more or less normally, and is certainly more reasonable than the startling deviation revealed by the face of returns, and the explanation is more acceptable to reason than that urged by the Census Bureau, of a sudden and unexplainable decline in the negro birth rate.

It is a source of surprise to note that the American mind seems to expect that any fact which affects the negro will deviate from the normal course of human values. It is prone to accept with satisfaction wild assertions and unsupported theories, without subjecting them to the test of logic and reason. If it is seen in the Census, it is so. Any statement issued upon the authority of the government which seems to be belittling to the negro will be seized upon by would-be social philosophers and exploited throughout the nation to the disadvantage of the race.

De Bow, relying upon the low rate of increase in the negro population, revealed by the census of 1870, proved to the entire satisfaction of those who were satisfied with this type of proof

that the negro could not withstand the competition of freedom and would, forthwith, fall out of the equation as an affected factor. The census of 1880, showing the unheard of increase of 34 per cent., set all of De Bow's philosophy at naught. But thence arose another school of philosophers which declared that this unheard of increase in the negro population threatened the numerical ascendancy of the white race, and, therefore, the black man should be returned to Africa from whence his ancestors came. The census of 1890 refuted this conclusion by showing only an increase of 13.8 per cent., but, no whit abashed, another type of anti-negro propagandism arose, declaring that the rapid decline in the race indicated inherent, degenerative physical tendencies threatening to the health and stamina of the American people. The census of 1900, showing a rise of decadal growth to 18.0 per cent., produced a calm in the domain of social speculation. But the preceding prophecies of evil are still of record. It seems to be the nature of the prophet to ignore the failure of the fulfillment of his prophecies.

It is particularly unfortunate that such loose and unscientific propaganda can be bolstered up by data from governmental documents which the uninquiring mind is disposed to accept with the authority of holy writ. The calamity philosophers have already dipped their pens in ink to damn the negro race to degeneration and death by reason of the latest census figures. The thought, and perhaps the conduct, of the nation may be misled on the basis of erroneous data, backed up by governmental authority.

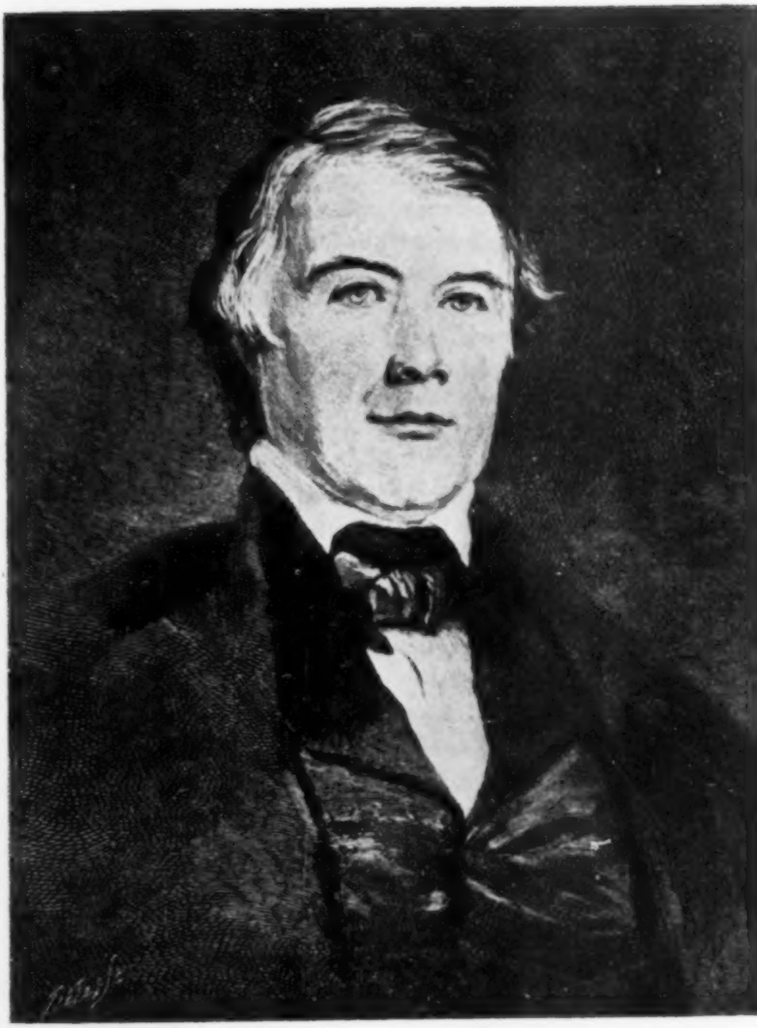
The broader question arises in the scientific mind. If the data on negro population furnished by the census can not be relied on, as is clearly shown by past enumerations, what assurance is there that collateral information, such as death rate, birth rate, occupation, illiteracy, etc., are to be given full credit and confidence. The negro problem is the most complicated issue with which we have to deal. Straight thinking and sound opinion based upon accurate data are absolutely necessary to enable us to reach any conclusion of value. The Census Office has now become a permanent bureau, which, it is hoped, will take rank with other scientific departments of the government.

Statesmen and publicists should have serious concern about the accuracy of negro statistics in view of the importance of the political and sociological conclusions based upon and derived from them.

WEATHER CONTROL

By Professor D. W. HERING
NEW YORK UNIVERSITY

IT is not in human nature to suffer from a prolonged or repeated evil without seeking for a remedy. Severe weather of any kind—heat, cold, rain or drought—if long continued causes distress and the only way to escape the ill effects of such extremes is to control the weather, either to mitigate it when it is becoming too severe or to take proper measures in advance to secure the kind of weather that is wanted. Savages and unenlightened peoples have resorted to all sorts of charms and incantations; to medicine-men, rainmakers, rain-gods, etc. These mummeries have been the subject of many articles and some elaborate treatises. The ceremonies are often curious and ingenious; some are grossly superstitious and others are mere chicanery, but usually the method of the rainmaker among primitive folk is based on homeopathy or imitative magic—for instance, he will attempt to produce a noise like thunder with the idea that this will result in the bursting forth of the genuine article and its attendant rain; or he will subject puss to an enforced bath in spite of her repugnance to it to bring about a rain, inasmuch as when she washes her face it is a sign that rain is coming. These practices have been common also with pagan nations of the highest civilization. Jupiter Pluvius was one of the most potent of the Roman Deities, and of course when the gods controlling the elements are angry they must be propitiated by suitable ceremonies. For excessive cold we provide extra means of heating, for tornadoes cyclone cellars, excessive rainfall and floods present problems for the engineer if he would ward off the destruction they would cause; these measures have reference to individuals or to isolated places, but the actual control—the production, prevention, or moderation of any special kind of weather over large districts—has not been accomplished or even attempted in the case of heat, frost or winds, though it has been undertaken with regard to the production of rain, and, according to Professor McAdie, of the U. S. Weather Bureau, meteorologists are of the opinion that "rain-control is a scientific possibility. Successful rain engineers will come, in time, from the ranks of those who study and clearly understand the physical



(Courtesy of D. Appleton and Co.)

PORTRAIT OF JAMES POLLARD ESPY ("OLD STORM KING")

process of cloud formation." The modern rainmaker therefore can be nothing if he is not scientific. He must have a scientific ground for his process however fallacious it may be.

If any one can be called the Father of the United States Weather Service, it is James Pollard Espy (1785-1860). From his meteorological studies he evolved a theory of the manner in which clouds are formed in high regions of the atmosphere and produce rain. This was to the effect, essentially, that heated air at any locality rises into rarer regions and expands; this expansion is accompanied by fall of temperature which condenses the vapor in the immediately contiguous air as well as within the ascending column; this condensation liberates sufficient heat to stimulate the further rise of the central column of air, with continuous expansion, cooling, and condensation of vapor into clouds, until they are eventually precipitated as rain.

He thought that this natural process could be accomplished artificially by maintaining large fires over extensive areas, and sought governmental aid to undertake experiments for that purpose. He cited the practice of American Indians in burning the prairies to produce rain, and his agitation of the subject attracted so much attention that numerous instances were reported which seemed to confirm his theories, but his petitions to the legislature of Pennsylvania and to Congress were humorously refused. He acquired high repute as a meteorologist in Europe as well as at home, and in 1841 he published his *Philosophy of Storms* which included his proposed method of producing rain artificially. In 1843 he was placed in charge of the meteorological work of the U. S. Signal Service, his division being known as the Meteorological Bureau of the War Department, in the conduct of which he became familiarly known as "Old Storm King"—a sobriquet which meant that if the public regarded his theories as vagaries, they thought none the less kindly of him on that account. His branch of service was afterwards transferred to the Department of Agriculture, and continued as the U. S. Weather Bureau.

Although Espy's theories are now know to be not wholly sound, their promulgation was a great incentive to further work along their line. The many instances of rain occurring either during or immediately after a severe battle or heavy cannonading had been often commented upon, and in 1871 Mr. Edward Powers published a book on "War and the Weather" containing a large collection of data to show that heavy cannonading was followed even in very dry regions by copious rainfall. He developed a theory that although concussion did not cause the formation of clouds in the surface atmosphere, which was lacking in moisture, in some

way it did cause precipitation from the higher strata of air which carried moisture. His contention all turned upon the question whether, in the United States, in times of drouth at the surface of the earth, the upper air has a considerable supply of moisture derived not from surface evaporation, but brought from the Pacific ocean; that "it is not the moisture of the surface air east of the mountains that causes the rain; it is the rain that causes the moisture." The idea that at a great height there is a generally prevalent flow of air eastward and above that a stratum flowing westward is still entertained, and aviators are seeking to determine whether it is correct.

As might have been expected, Mr. Powers' theory too was pooh-poohed, but his arguments and illustrations were too cogent to be ignored, and the prospect of large financial benefit that might be obtained from a successful application of these ideas in the production of rain was alluring enough to induce capitalists to finance an attempt on a large scale. The national government went so far in its sanction of the enterprise as to authorize an expedition for the purpose of conducting experiments under the direction of General R. G. Dyrenforth. The Midland Ranch, in the northwestern part of Texas, was selected for the place to conduct the experiments, which were frequent and varied, during the period from the ninth to the twenty-fifth of August, 1891. Both the place and the season were thought to be above rather than below average dryness. The affair attracted much attention, and reports of the experiments were read eagerly throughout the whole country. Various forms of bombs and balloons were used to produce explosions and concussions at different altitudes. General Dyrenforth's report to Congress, (Senate: *Ex. Doc. No.* 45, February 25, 1892), was to the effect that the experiments were not extensive enough or sufficiently long continued to make safe deductions; and Mr. George E. Curtis, who was meteorologist for the expedition, concluded that "these experiments have not afforded any scientific standing to the theory that rain-storms can be produced by concussions." At the same time, the leaders and participants in this expedition did not think the theory was disproved, and its advocates regarded the tests as insufficient. Much discussion followed. Professor Alexander McFarlane, of the University of Texas, in a letter to the San Antonio Daily Express, of December 4, 1891, said "The trial of Friday, August 25, was a crucial test, and resulted not only in demonstrating what every person who has any sound knowledge of physics knows that it is impossible to produce rain by making a great noise, but also that even the explosion of a twelve-foot balloon inside a black rain cloud does not

bring down a shower." This "crucial test," however, was followed next day by a precipitation that was characterized by different persons as anything from a mere sprinkle to a heavy rainfall, two or three miles to the northwest of the place where the experiment was made, but in a direction in which the wind would have carried the clouds. It was not certain that the rain was due to the explosions, and it was unfortunate that the experiments resulted in this negative fashion and were inconclusive. One consequence of these efforts, especially to be noted, is related by Mr. Curtis. He calls attention to the rash conclusions that were drawn from the telegraphic and incomplete reports of the effect even of preliminary experiments and trying out of the apparatus, and adds "charlatans and sharpers have not been slow to seize the opportunity thus afforded. Artificial rain companies have sprung up and are now (1892) busily engaged in defrauding the farmers of the semi-arid States by contracting to produce rain, and by selling rights to use their various methods."

Thirty years have elapsed since the Dyrenforth experiments—what has become of the weather mongers' pseudo-scientific pretensions and practices? As lately as February 1, 1921, the public press reported from *Medicine Hat, Alberta,* the announcement by the United Agricultural Association that "Rainmaker" Hatfield *had been engaged to increase precipitation* during the dry season at the rate (*sic*) of $4,000 an inch. The "Rainmaker" says he can produce rainfall by chemical and other scientific methods, and is to operate over a section of about one hundred miles radius. That last is a very clever stipulation. It greatly increases his chance of success and makes it much safer for him to guarantee it, for a circle of one hundred miles radius covers just a hundred times as large an area as one of ten miles radius and gives him one hundred times as great likelihood of apparent success *somewhere,* as if the region of his efforts were the smaller district.

A sequel to this appears in later dispatches from Milwaukee, in which Wisconsin farmers are said to offer "Rainmaker" Hatfield $3,000 an inch for producing rain. The item states further that "Hatfield has made rain for the farmers in three counties in Washington State, where he was paid $3,000 an inch. His rainmaking equipment consists of a huge tank 20 feet high in which Hatfield brews a mystic chemical mixture which, he says, opens up the clouds." (New York Times, July 27, 1921.)

There is here the same difficulty in tracing any connection between supposed cause and effect—the same kind of difficulty, that is present in the pretensions of the dowser. The operator goes through his performance, (so does the Indian medicine-man);

somewhere in some measure, rain falls; and the blunder, as old as man, of counfounding *post quod* with *propter quod*, continues.

The process of passing from aqueous vapor through clouds to rain is not yet well determined and the rainmaker, who must perforce be scientific, is obliged to proceed in a manner that he can show conforms to "theory." Unfortunately there is a superabundance of theories—at least five, and all have good scientific support, while not one is conclusively established to the exclusion of the others. The rainmaker favors a combination of two; (a), that dust nuclei should be in the air, about which water vapor can gather, (smoke, either from surface fires or exploded bombs will meet this need); and (b), that jars or concussions will so jostle or disturb the air that the water particles will attach themselves to these nuclei. The process of coalescence begun, it will continue of itself although the exact reasons for so doing are not altogether understood; or at least physicists are not agreed upon them. This, however, is not the rainmaker's concern so long as they do act. Mr. McAdie flouts the concussion idea. He says "Rainmakers of our time bang and thrash the air, hoping to cause rain by concussion. They may well be compared to impatient children hammering on reservoirs in a vain endeavor to make water flow."

That was written in 1895, but in 1918, nearly a quarter of a century later, a popular old English almanac, *Raphael's Almanac or the prophetic Messenger and Weather Guide*, gives this caution to its readers:

> No reliance should be placed on weather predictions during the war, as the terrific bombardments cause violent concussions in the atmosphere, producing clouds and rain, particularly in the southeast and east of England.

Weather control by artificial means, however, is not regarded as unscientific, and meteorologists are not hopeless of ultimate success in accomplishing it, at least in producing rain. At the time of the Dyrenforth experiments the psychologist, Elmer Gates, was demonstrating in his laboratory at Chevy Chase, Maryland, the production of rain electrically. Electrifying the air at one spot, (like a limited area of the earth's surface), causes expansion by the mutual repulsion of air particles; the air becomes less dense and rises, currents thus set up encounter colder air in the upper regions, and moisture is precipitated.

Various processes for rain-making have been patented, and the business is carried on with a good deal of financial success by the dowsers of the clouds. They succeed in getting testimonials apparently with little difficulty, in which the witnesses testify to things as of their own knowledge, which occur simultaneously in places twenty miles or more apart, and similar inconsistencies.

(*Courtesy of Everybody's Magazine, and the Artist, Jules Guerin*)

ILLUSTRATION OF SHOOTING AWAY HAIL STORMS

When clouds take on a sinister aspect it behooves man to do what he can to fend off the injury which they threaten. A hailstorm may work havoc, and in a few minutes may wreck all the hopes which the agriculturist has erected upon the labors of an entire season. It means disaster. Especially has this been the case in the rich wine-growing districts of France, Italy and Austria. Hailstorms are not uncommon there, but familiarity does not breed contempt. The growers have learned to recognize pretty readily the signs of such storms, which cover usually a small area; and the clouds from which the hail falls are massed in a limited region or pass over a narrow strip of territory.

After various haphazard experiences of viticulturists, one of them, an Austrian, Albert Stiger, invented a form of cannon in 1896 which could be readily and effectively used for the purpose of repelling and breaking up such storms. This cannon somewhat resembles the old bell-mouthed blunderbuss in form, with a chamber at the breach for a cartridge containing only powder, and a funnel shaped tube like the cone of a megaphone. Housed in little shacks on the hillsides, these are ready for use at short notice, and since they are distributed among the many adjoining vineyards, a whole battery of them can be brought into action promptly. The grapes are maturing and the vineyards are in their most vigorous growth from July to September, just at the time of year when hailstorms are most frequent, and the workmen accordingly are alert in watching for signs of danger. When the storm is seen to be gathering, the cannons are brought out and directed against the threatening cloud. Signals are sent from vineyard to vineyard and upon the first appearance of the destructive hailstone the counter bombardment begins. From the mouth of the cannon issues a mass of heated gas, smoke and smoke rings, propelled violently against the lowering cloud. The smoke rings are like those discharged from the smoke stack by the puffs of a locomotive, but with far greater energy of propulsion. In a sense this was anticipating the war, for it was a veritable gas attack in the realm of the aeronaut. The theory of the action is not very definite or well assured. Whether the rings of smoke disrupt the clouds, or whether sufficient local heating of the air causes warm air to rise and intercept the hail, converting it into rain or preventing the congealing of water vapor into hail, is uncertain; but there seems sufficient evidence of the efficacy of the plan in dispersing the clouds and checking the storm of hail. The cannons literally *shoot it away.*

LAKE Pepin is caused by the delta of the Chippewa River, which dams up the Mississippi. It is thirty miles long and has an average depth of about twenty-five feet. Its waters support many fishes and clams which are of commercial value. In order to give a picture of the life of the fishermen, the routine of a typical day at the end of June is described.

The wren that lived in the tomato can we had nailed to the tree beside our shack sang at four o'clock, as usual. I lay in my cot and drowsily thought of Chaucer's couplet:

> And small foules, a great hep,
> That had afroyed me out of slepe.

The wren sang again and then I heard the lapping of the river on the sand. The water sounded so near that I peeked over the side

THE MINNESOTA BLUFFS

OUR HOME FOR A MONTH

of the cot to see if it was in the shack, but the floor was dry. With clothes in one hand and boots in the other, I sneaked out on our front porch, which consisted of a barn door that we had salvaged from the river. The mighty provider of porches had risen eight inches during the night and was busily engaged in hurrying trees, logs and all sorts of riff raff toward New Orleans.

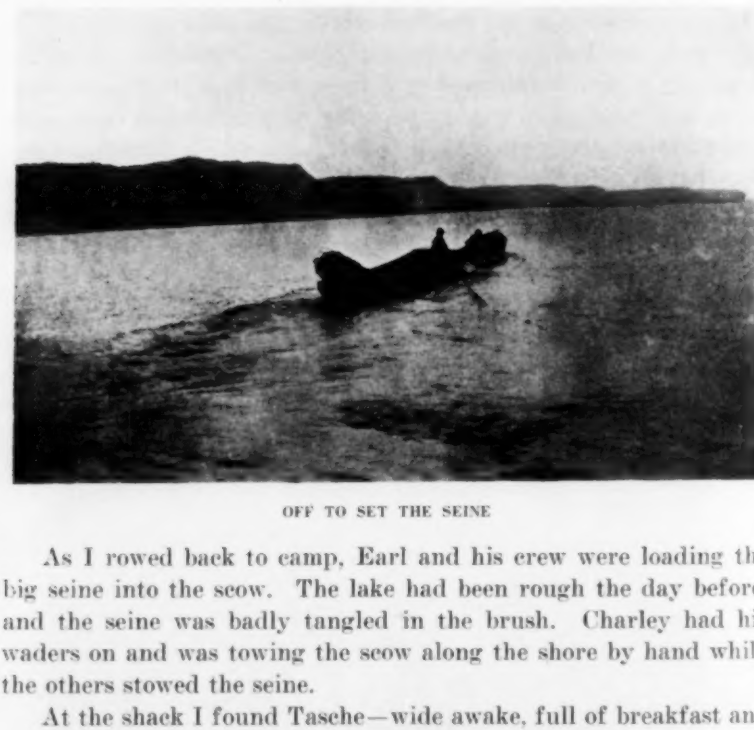
The sun touched the Minnesota bluffs. Ghostly clouds of mist crept over Lake Pepin. I pulled on my boots and washed. The wren sang some more. Another day had begun.

I ate my breakfast, then rubbed the spoon and pan in the sand at the margin of the river, rinsed them at the pump, and stood them on the table to dry. We rejoiced in a regular cistern pump, which, driven in the sand, gave us plenty of clear, cool water. The Israelites with Moses were no more appreciative than we!

OUR LABORATORY

I slid the skiff gently into the river and pulled against the current out on Lake Pepin. As I left our cove, I could hear the "put-put" of Earl's engine as he brought his launch around to take out the scow. At night Earl always put the launch in the slough behind the bar, safe from storms. He had a fine start this morning and should, with luck, have his seine out at ten o'clock.

The gill nets did good work. They had been set in the deepest part of the lake (55 feet) and I was rewarded for the long pull with sixteen hacklebacks,[1] two saugers, a channel cat, and two clams. There was a big carp in the two-inch mesh net and I got him to the very surface of the water. But the net was rotten and he was caught only by the saw-spine on his dorsal fin. Just as I was slipping the dip net under him—a mighty flop, and he was gone! The clams were without pearls, too. But we would have hackleback for dinner!



OFF TO SET THE SEINE

As I rowed back to camp, Earl and his crew were loading the big seine into the scow. The lake had been rough the day before, and the seine was badly tangled in the brush. Charley had his waders on and was towing the scow along the shore by hand while the others stowed the seine.

At the shack I found Tasche—wide awake, full of breakfast and ready to go out to the trot-line. Jean was already spearing carp. As soon as my catch was unloaded, Tasche jumped into the skiff and rowed away up the big slough. I had scarcely taken care of

[1] Sand-sturgeon, *Scaphyrhynchus platorhynchus* (Rafinesque).

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HAULING THE SEINE

the fishes from the gill net and straightened up the shack a little, when he was back. I knew by the splash of his oars and the set of his back that he had something. But we went through the regular formula for such occasions. I hailed:

What luck?
Pretty fair.
The skiff dug its nose into the sand and Tasche said,
Got some more channel-cats.
How many?
Three. One of them about five pounds.
Anything else?
Why, yes. I got an eel!

DIPPING THE HAUL INTO THE SKOW

HAULING THE SEINE

With a whoop I ran down the beach. This was the only eel we got all summer! It was a fine old fellow, about three feet long. Tasche held it up, still attached to a leader from the trot-line.

"I was afraid to take him off. He's too slippery to hold!", he said.

It was a strange fish with a strange history—hatched in the Atlantic Ocean and caught a thousand miles up the Mississippi. We made a hasty examination of the eel and put the other fishes in the "live car" for future study. We were anxious to be at the hauling of the big seine.

As it turned out we had plenty of time, for the seine was not quite loaded when we reached the lake. It was soon on board the scow, however, and five minutes later Earl was towing it out into the lake. Earl handled the launch and Floyd, on board the scow, watched the line that was fastened to a tree on shore and "paid out" as they went along. When the line was out, Earl turned his course parallel to the shore to spread the seine. The great net was 2,000 feet long and 28 feet deep. The mesh was two and a half inches, bar measure; except a hundred and fifty feet in the center, which was two inches. After the net was out, Earl turned directly toward the shore while Floyd paid out another hauling line.

Floyd waded ashore with the end of the line, slipped it through a pulley which was lashed to a sturdy stump, and then handed it to Charley. That worthy took a couple of turns around the wheel of his hoisting engine—already popping away at a good rate.

The hauling of the seine took about two hours. First a long

line came ashore and was neatly coiled. Then the wooden brail at one end of the net appeared above the water. Two of the boys pulled a hauling line down the beach to where the line from the other end of the net was fastened. They rigged another pulley and, without moving the hoisting engine, began hauling again. Another line was coiled down and finally the brail at the other end of the net crawled slowly up the beach.

When the brail got almost to the pulley, George threw the line off the engine and the hauling stopped. Earl took the end of the line out into the lake until the water was above his waist, stuck his toe under the bottom of the net and raised it so that he could grasp it with his hands. The hauling line was made fast to the lead line. Earl signaled to George and the net began to come on shore. Floyd and Charley took stations about thirty feet away from the water on either side of the net, which they stretched and piled down neatly on the sand to dry. Every time the knot on the lead line came up to the pulley, Earl waded out and fastened the hauling line further along the net.

Earl was "boss" because he was, physically and mentally, the best man of the crew. He had travelled all over the United States and served in France during the war. At thirty-three he had come back to his old home on the Mississippi and settled down to spend his life as a seiner—because he loved the outdoors and fishing, and rejoiced in hard work as a strong man should. He always took the hardest tasks; and indeed no other in the crew could do them as well. Altogether Earl was as honorable and rough and fair and profane and instinctively courteous as one could wish—a real man who asked no favors and expected to give none, but would when you least expected it.

When nearly half the net was in, the hauling line was changed

DIPPING THE HAUL INTO THE SKOW

DRYING THE NET

to the other end and another period of stretching and piling ensued. At ten o'clock there were only a few hundred feet of the seine left in the lake. Earl waved his arms and George stopped the engine. All the crew then began pulling in the "center" by hand. As the space between the seine and the shore grew narrower, the fish began to flop. A twenty-pound carp flipped over the top of the seine and Earl yell to old Charley.

"Hold up that cork line! G——! They'll go like a flock of sheep." And Charley "held up."

"There's a big spoonbill!" said George. "They've been awful scarce this year. Twenty years ago we used to get a thousand pounds a day."

"Shut up," said Earl. This was no time to spin yarns.

Finally the net was in and the crew gathered around in a little circle, holding the edges of the net well above the water so that no

LOADING THE NET ON TO THE SKOW

high jumper could escape. Tasche and I lent a hand while Floyd brought up the scow. Then Earl took a dip net, stepped among the flopping fishes, and "ladled" the catch into the scow.

There were many carp weighing from fifteen to twenty pounds—great, glittering, golden fellows that taxed even Earl's sturdy muscles. There was also a good number of sheepshead, river carp (which the Lake Pepin fishermen call "white carp"), red horses, and a mud cat—all marketable fishes. The prize of the day was a forty-two pound spoonbill. At the tail of the catch were about sixty mooneyes—beautiful, silvery fishes—which Earl saved. Mooneyes are not fit for human food, but are ground up and used as an ingredient of chicken feed.

THE HAUL

The game fishes were all put back into the water as soon as possible. It fills an unsuccessful fisherman with regret to see ten-pound pickerel and wall-eyed pike cast back into the lake. George also threw back about fifty black bass, white bass, blue-gills, and crappies.

As soon as the catch was all on board the scow, Floyd jumped into the flopping mass and began putting the small carp and buffalo back into the lake. He also recovered a few game fishes that had not been previously thrown out. Earl meanwhile was bringing up the launch and before Floyd had all the "culls" overboard he was on the way to Pepin. In half an hour after the catch left the net it was on ice in Jim Broatch's fish house, and that evening some of

THE NET IS IN

the fishes were on sale in Minneapolis and Chicago. The best part of the catch, however, was sold in St. Louis and New York two or three days later.

After the "haul" had gone to town, Charley and George pulled in the center of the net and spread it neatly on the sand. A big pike had turned belly up and was floating along the beach.

"He'll never live," said Charley. "I believe I'll cook him for dinner."

"What sort of fish do you fellows usually eat?" I asked. Charley evidently thought I was too curious on short acquaintance and did not answer. George, however, who could not forego an opportunity to say something, after pondering a moment said,

"Well, we mostly eat carp and sucker."

Tasche and I went back to the shack. As we came down the shore a big softshell turtle ran from a sand bar where she had been digging a nest. She scuttled awkwardly but swiftly down to the water, leaving a trail like a caravan.

We dined on fried sturgeon at our table under a willow tree. For dinner, sturgeon is the king of all fresh-water fishes. After the skin is off and the "chord" has been pulled out, there are no bones. The flavor is delicious and, when well cooked, a sturgeon "melts in the mouth."

The softshell climbed out on the bar again while we ate. She found a spot that suited her and began to throw spurts of sand out behind. We tried to slip away from the table without being noticed, but she gave us one neck-stretching look, then tore down the beach and disappeared into the water with a grand splash. We saw her no more.

After dinner we went up to the seiners' shack and talked a while. Sitting on the sand we had a magnificent view across the river to the tree-covered Minnesota bluffs, which tower four hundred feet above the water. As we talked scores of swallows hunted over the bars. Floyd spent all his leisure whittling. Today he was working on an American eagle perched on a ball. He finally cut a great gash in his finger and Earl tied it up. Talk drifted on from women to high prices, and from high prices to war, and finally to fishing. I asked the boys concerning the number and variety of fishes they caught in the big seine. After some debate Earl made the following estimate of the average catch per day during the season (June 15 to November 15), and the others agreed that it was "about right:"

Carp, both "German" and "river"	500 lbs.
Dogfish (1,000 lbs. on some days in autumn)	400 lbs.
Sheepshead	350 lbs.
Suckers and redhorses	200 lbs.
Wall-eyed pike	200 lbs.
Mooneye	100 lbs.
Pickerel	50 lbs.
Buffalo	25 lbs.
Spoonbill	25 lbs.
Catfishes and bullheads	25 lbs.
White bass	10 lbs.

LOADING THE NET ON THE SKOW

THE SEINING CREW

Black bass (two species)	10 lbs.
Bluegill	1 lb.
Crappies	1 lb.

At three o'clock the crew started loading the seine into the scow. Tasche and I got out the minnow seine and dragged along the shore to catch bait for the trot line. We caught a lot of shiners, a few little suckers, about two hundred log-perch, and a tadpole cat. While we were seining Jean came back from the sloughs with

CHARLEY

thirty-two carp that he had speared. Once he had lunged too far and slid over the bow of his boat. His clothes were still wet—and his language scandalous! Jean cleaned his catch and left for Pepin, where his carp would soak in brine overnight and be ready for smoking the next morning.

A fly fisherman tried his luck past our shack. He was an aristocrat among fishermen, with a man to row for him and a beau-

TASCHE WITH HIS CATFISHES

tiful outfit, and he knew his business. Drifting along near shore, his fly fell forty feet away in the exact spot that he chose and it flickered over the water in a way to make any bass long for it. We did not begrudge this fisherman the two fine bass that came into his landing net. He deserved them!

After supper Tasche rowed up into the slough and set the trot line. I sat by the fire, cooking rice and dried apples for breakfast. Before nine o'clock we had our cots set up and were spreading

TASCHE "RUNNING" THE LINE

our soggy garments out for the night. As I dozed off the hoot owl started his nightly refrain.

And smale foules maken melodie
That slepen alle night with open eye.

The United States has resources of great commercial value in its larger lakes and rivers. Though there are many fishes in swamps, creeks and ponds, such small bodies of water can never furnish great enough numbers to be of value to commerce. Their resources should be conserved, however, for the sportsman and small boy. Every fish caught on a hook and line probably costs dollars in tackle and time, but it is worth what it costs in health and the wealth of spirit which accrues to those who live outdoors.

There has always been some conflict of interests between those who fish for the market and those who fish for sport or to get a fresh dinner. The one wants a continued supply of large fishes; the other is after a few fine specimens that he can show his neighbor with pride—caught by himself! There will always be these two classes of fishermen and civilization must keep a place for them.

The citizens of the United States have already committed some errors in the administration of the fisheries resources in the Mississippi River. Aggressive and interested sportsmen have secured the passage of certain laws; those concerned in making money have fathered concessions which helped their business. There has been a deal of prejudice, misunderstanding, and thoughtlessness. To a scientist, such conflict seems unnecessary.

The "ultimate" food resources for the animals in the Missis-

sippi are in the aquatic vegetation. Water plants, given solar energy, can make living substance from minerals, water, and carbon dioxide. As animals cannot do this, they depend on plants for food, directly or indirectly. The Mississippi River itself does not contain many plants. Its bottom shifts too rapidly and its water is usually too turbid to permit the passage of solar energy to any except very shallow depths. Its chief value for fishes is as a highway through which passage is permitted to the great stores of food in tributary swamps, ponds, and other situations where plants flourish.

What are the foods of the chief commercial fishes? The carp is omnivorous, but its food is chiefly vegetation. It does great damage to aquatic plants, grubbing up wild celery and other plants which might afford food and shelter for ducks and game. Its best feeding grounds are in swamps. The dogfish feeds largely on crawfishes and minnows. The sheepshead eats snails, clams, and mud. The suckers and red horses feed chiefly on mud and the small organisms associated with it. All these fishes of commercial importance as food do injury to man. The carp destroys vegetation; the dogfish eats game fishes; the sheepshead, and to some extent the carp, devour many young clams which might otherwise grow large enough to be made into buttons. Suckers and carp follow other fishes when spawning and eat their eggs. In all respects it is desirable that the resources represented by these four

TASCHE AND THE EEL

food fishes be conserved, by preserving swamp areas and sloughs, and it is also desirable to keep catching the larger fishes continually in order to check the injury they may do. The sportsman who talks of prohibiting seining, while fishing by "sportsman's" methods continues, is advocating the unchecked increase of "rough" fishes which will compete with the game fishes in aquatic habitats. Wise, supervised seining is one of the best means of increasing game fishes.

The fishes the sportsman most loves are insect and fish eaters. Both the favorite foods of these fishes are usually associated with aquatic plants. The bass hunt among aquatic vegetation for immature insects and skim the surface for adults; the pickerel and pike lurk along the margins of water gardens, ready to snap up any small fish that passes. These fishes are most often found where water plants grow abundantly.

There have been marked changes in Lake Pepin during the past decade. Time was when a seiner caught a thousand pounds of spoonbills every day and when buffaloes were second in commercial importance only to spoonbills. Big sturgeon were also common. Now these fishes are scarce; the carp, sheepshead and, once despised, dogfish have taken their places in the markets. Fish epicures have been obliged to lower their standards. The causes of the decrease of the more desirable food fishes is uncertain. Perhaps overfishing, the introduction of the carp, the pollution of the river by industrial wastes, and the construction of dams have contributed, but there is no satisfactory scientific explanation.

A great natural asset like Lake Pepin should be appreciated—natural reservoir, source of free food for the poor man, livelihood for the fisherman, recreation for rich and poor. It is worth much to the nation. The Mississippi is an opportunity—for science to gain a knowledge of causes, for the government to conserve and improve valuable resources.

FLOWER SEASONS

By CHARLES ROBERTSON
CARLINVILLE, ILLINOIS

THE statements made here are based upon observations made from 1884 to 1913, at Carlinville, Illinois, regarding the blooming seasons of 470 indigenous and 54 introduced entomophilous (insect pollinated) flowers. Twenty-three native and seven introduced species, with an average of five days, are excluded as fragmentary. The blooming time of each flower includes early dates for early seasons and late dates for late ones, and is therefore, when correct, longer than the time for a single season. Unless otherwise specified the statements relate to indigenous species.

March—The season opens on the 15th and shows only 21 plants in bloom for the month. Nevertheless, March shows the highest percentages of trees, 19.0; shrubs, 14.3; woody plants in general, 33.3; acaulescent herbs, 23.8; and white flowers, 57.1; Salicaceæ, 9.5; Parietales, 23.8; Ranales, 19.0; Caryophyllales, 14.2;, and Polemoniales, 9.5; Thalamifloræ, 61.9, and Archiclamydeæ, 85.7—all of the characteristic early groups, except Monocotyledons and woody climbers.

April—This month shows the highest percentages of flowers coming in bloom, 78.6; greenish-yellow flowers, 17.4, and non-social flowers, 75.7; Coronarieæ, 9.7; Ranunculaceæ, 11.6; Cruciferæ, 8.7; Rosaceæ, 8.7; Liliaceæ, 8.7, and Violaceæ, 7. 7. The Parietales and Salicaceæ show April maxima.

May—The following show May maxima: Monocotyledons, Thalamifloræ and Archiclymydeæ; Ranales, Coronarieæ and Umbellales; Orchidaceæ, Caryophyllaceæ, Rosaceæ, Ranunculaceæ, Cruciferæ, Liliaceæ and Umbelliferæ; trees, woody plants in general, pendulous flowers and greenish-yellow flowers. May shows the highest percentages of Calycifloræ, 29.1; Monocotyledons, 14.0, and Umbelliferæ, 6.0. Half the families with more than six species have May maxima. May shows more suborders, families and genera than August, and more families at the maximum, but the groups are represented by fewer species. Therefore, if the fourteen families with more than six species are thrown together, August will show the maximum of species. Only 16.5 per cent. of May flowers bloom through the month, while 58.6 per cent. of August flowers

are continuous. The Inferæ begin to form a marked element of the flora.

June—No dominant groups, except Polemoniales, show a maximum in June. They have less influence in the composition of the June flora than in that of any other month. All are declining from an early maximum or rising to a late one. June shows a maximum of woody climbers, all of the species blooming in the month, and of shrubs, but fewer species than in May. It is the most heterogeneous, having the most orders and the most families, and more genera than any other month except July, which has the same number.

June has the most discontinuous blooming seasons. The Scrophulariaceæ, Rosales, Parietales and Thalamifloræ show depressions. June 2 has fewer flowers in bloom than any other day from May 10 to September 24. More species, and a higher percentage of species, go out of bloom than in any other month except September and October, which close the season. In number beginning to bloom it is exceeded only by July. Uniting those beginning and ending gives the highest number for any month. The difference between the percentage of flowers and the percentage in bloom together is greatest for June. The Personales, Lamiales, Compositæ and Papilionaceæ enter as important elements of the flora.

July—The Calycifloræ, Bicarpellatæ, Rosales, Gentianales, Asclepiadaceæ, Papilionaceæ, white flowers, and introduced plants show July maxima. It has the highest percentages of perennial herbs, 72.0, Rosales, 16.4, and Papilionaceæ, 10.0. The Bicarpellatæ for the first time surpass the Calycifloræ. The dark colors begin to preponderate over yellow, including greenish-yellow. Woody plants form only 8.0 per cent. of the July flora. It shows the most flowers beginning to bloom, and more genera than any other month except June, which has the same number.

Comparing July and August gives the following percentages: Of the flora, 53.1, 51.4; of flowers of the month blooming through the month, 37.6, 58.6; of flora in bloom at maximum, 41.7, 42.7. July has the most flowers in bloom, but fails to show the maximum on account of less continuous blooming.

August—This month shows maxima for Inferæ, Asterales, Compositæ, Alismaceæ, the general entomophilous flora, zygomorphous, dark colored, yellow flowers and perennial herbs. The most remarkable thing about August is that 142 of its species, 58,6 per cent., bloom through the month. The nearest approach to this is July with only 94 species, 37.6 per cent. continuous. This is directly connected with the long blooming seasons of the later flowers. The effect of this is that July, while it has eight more species in bloom

in the month, shows five less in bloom simultaneously and that only on the last day. In the case of the Asterales, also, there are three more species in bloom in September, but one less at the highest point of those in bloom together. The position of the principal groups of Dicotyledons is just the reverse of what is found in May. August differs from May in having fewer dominant maxima, but in having more species in each. Only 16.5 per cent. of May flowers are continuous, while 58.6 per cent. of August flowers are so. August has the highest percentage of Personales, 7.4.

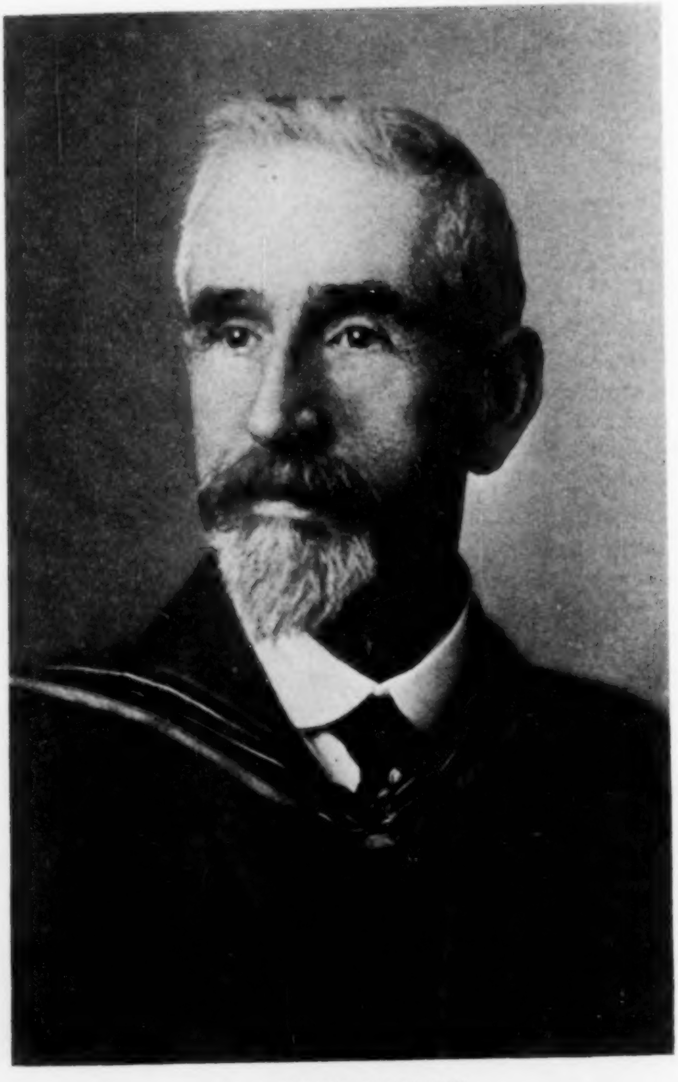
September—The characteristic of September is the decline of general flora. While in August only 51 plants, 21.0 per cent., go out of bloom, in September 115, 57.2 per cent., do so. September shows the highest percentages of dark flowers, 32.3, yellow, 29.3, Lamiales, 11.4, and Labiatæ, 8.9. It shows a maximum for Convolvulaceæ.

October—The flora is 24.7 per cent. less than in August and 3.9 less than April. It has the highest percentages of social flowers, 60.4; annuals and biennials, 42.3; Asterales, 47.0; Polygonaceæ, 9.4; Inferæ, 50.6, and Sympetalæ, 70.5.

A peculiarity of October is connected with the differences in the blooming habits of indigenous and introduced plants. The indigenous ones bloom a shorter time and have become adjusted to the climate so that they decline in anticipation of the approaching cold. The introduced plants average twice as long and often quit blooming only when they are frozen. In October 18.0 per cent. of the indigenous and 64.1 per cent. of the introduced plants are in bloom. While the introduced plants are only 10.1 per cent. of the total flora, they are 28.5 per cent. of the flowers in bloom in October, 39.1 per cent. of the flowers blooming after October 16th.

Another peculiarity of October is that the Thalamifloræ predominate over the Calycifloræ for the first time since April. This helps to explain the higher percentage of white flowers in October over September.

November—This is altogether fragmentary and shows only in unusually late seasons. There are eight indigenous, 57.1 per cent., and six introduced species, 42.8 per cent.



DR. J. PLAYFAIR McMURRICH

Professor of Anatomy in the University of Toronto, President of the American Association for the Advancement of Science.

THE PROGRESS OF SCIENCE[1]

THE TORONTO MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

At the meeting of the American Association for the Advancement of Science and of the associated scientific societies held at Toronto during Christmas week, the total registration was 1,832, and the number of papers and addresses presented before forty sections of the association and associated societies numbered about 900. The meeting was much larger than had been anticipated, partly through the participation of the citizens of Toronto and Ontario in accordance with the precedent set by the British Association. The number in attendance from the United States was 867. The arrangements made by the University of Toronto and the Royal Canadian Institute for scientific sessions and for the enjoyment of the visiting members were unusually complete. About 800 were provided with rooms and meals in the dormitories and halls of the university, and many of the dinners and social events were held on the university grounds.

The meeting of the scientific men of North America was both pleasant and useful and will lead to their closer cooperation for the advancement of science. Both this year and last a number of leading Canadian men of science were elected chairmen of the sections, and this year, for the first time since Sir William Dawson held the office in 1882, a Canadian was elected to the presidency. In accordance with the usual sequence of alternating between the exact and natural sciences, and from a number of distinguished men who were proposed, Dr. J. Playfair McMurrich, professor of anatomy in the University of Toronto, was elected. Dr. McMurrich's scientific research and publications have not been confined to human anatomy, but include comparative morphology, the factors of evolution and the history of science. Born and educated at Toronto, he has had wide experience in the universities of the United States, having received his doctorate ot philosophy and taught at the Johns Hopkins University, and having held chairs successively at Clark, Haverford, Cincinnati and Michigan, before accepting the professorship of anatomy at Toronto in 1907. Dr. McMurrich will preside at the meeting to be held next year at Boston, and will give his address at the meeting to be held the following year at Cincinnati.

The American Association holds its larger convocation week meetings once in four years, successively in New York, Chicago and Washington. It is planned that all the scientific workers of the country shall unite in these meetings and it is hoped that they will ultimately be joined by scholars who carry forward research in subjects not usually included under the natural and exact sciences. The meetings at the intervening two-year periods, as the one next year at Boston, are intended to bring together most of the associated societies. On the intervening alternate years, many of the special societies find it an advantage to meet separately in smaller university towns, where the personal contacts are closer. Thus this year the important groups of sciences devoted to anatomy, physiology, biological chemistry,

[1] Edited by Watson Davis, Science Service.

DR. WILLIAM BATESON, F.R.S.
Director of the John Innes Horticultural Institution, Merton, London

pharmacology and experimental pathology met at Yale University. The geologists, including the paleontologists and meteorologists, met at Amherst, an early center of geological science in America, whose traditions have for fifty years been carried forward by Professor B. K. Emerson, to whom a presentation was made. The geographers met at Washington, the astronomers at Swarthmore College, the anthropologists at the Brooklyn Institute and the psychologists at Princeton.

This somewhat wide scattering of the societies associated with the association made the success of the Toronto meeting the more notable. It has indeed often been the case that meetings more remote from the familiar centers have been especially enjoyable. Toronto is near the

SIR ROBERT FALCONER
President of the University of Toronto

northern limit of scientific activity, but it is convenient of access from the east and west. The University of Toronto and the city unite some of the characteristics of older and newer civilizations, and the meeting had features of the British Association.

Among them was the conferring of honorary degrees at a special convocation of the University of Toronto by Sir Robert Falconer, president of the university, on the presidents of the association for last year and this and on the guest from England, whose official appearances added much to the interest of the meeting.

The address by the retiring president, Dr. L. O. Howard, chief of the Bureau of Entomology of the United States Department of Agriculture, reviewed the war on insects, in which he himself has been a field marshal. Dr. Howard also reviewed preceding presidential addresses before the British and American Associations, with which he has had opportunity to become especially familiar in the course of the eighteen years during which he has been associated with a long line of distinguished men in his service as permanent secretary of the association.

Preceding Dr. Howard's address,

Sir Robert Falconer welcomed the association in admirable terms, and Professor E. H. Moore, of the University of Chicago, responded with felicity for the association. At the second general meeting, Dr. William Bateson, director of the John Innes Horticultural Institution at Merton, London, and present as the guest of the American Association and of the American Society of Zoologists, gave an address on "Evolutionary Faith and Modern Doubt," in which he argued that while the fact of evolution is not in question, the problems of the origin of species are still unsolved. Dr. Bateson paid a tribute to the "Stars that have arisen in the West," by whose work solutions have been found for many of the difficult problems of genetics, including the direct association of the chromosomes with the developing organism.

RESOLUTIONS OF THE AMERICAN ASSOCIATION CONCERNING THE PUBLIC WELFARE

The National Academy of Sciences is by law the scientific adviser of the government, but the American Association and the associated scientific societies have equal responsibility, representing as they do the consensus of opinion of scientific men. It may be hoped that in the future the council of the association, composed largely of delegates from the associated national societies, may take an active part in enlightening public opinion and in guiding legislation on problems concerned with the advancement of science and its applications to the public welfare. At Toronto several resolutions looking in this direction were adopted by the council.

It put on record its opposition to any action by which the Forest Service or the National Forests of the United States or of Alaska would be removed from the jurisdiction of the U. S. Department of Agriculture. The suspension of scientific periodicals issued by the government, such as the *Journal of Agricultural Research*, the *Experiment Station Record* and the *Monthly Weather Review*, was condemned. The introduction of non-native plants and animals into the national parks and all other unessential interference with natural conditions was opposed. A resolution declared that the American Association "recognizes the need and timeliness of fundamental research on the scientific principles which must underlie the formation, standardization and introduction of an international auxiliary language."

Noting that it had already affirmed its belief in the desirability of the adoption of the metric system by the United States, the council urged consideration by Congress of the metric bills before it.

The United States Commissioner of Fisheries having presented his resignation, the council went on record as emphasizing the prime importance of securing a man who possesses the special experience and scientific knowledge of the field, combined with the necessary administrative ability for discharging the duties of the position.

SCIENTIFIC ITEMS

WE record with regret the death of Henry Turner Eddy, professor emeritus of mathematics and mechanics in the University of Minnesota and dean emeritus of the graduate school; of Dr. Howard B. Cross, of the Rockefeller Institute for Medical Research, of yellow fever while studying that disease at Vera Cruz; of Henrietta Swan Jewett, of the Harvard College Observatory; of Earl Jerome Grimes, associate professor of biology at the College of William and Mary, and of Max Verworn, professor of physiology at the University of Bonn.